

Cognitive Load Study Using Increasingly Immersive Levels of Map-based Information Portrayal on the End User Device

by Elizabeth S. Redden, William Harris, David Miller, and Daniel D. Turner

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Human Research and Engineering Directorate, ARL

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14. ABSTRACT <p>This study was an investigation of the effect of the four different types of maps (2-D north up [2D-NU] map; 2-D rotating [2D-R], course up map; third-person perspective [3PP] map; and an augmented reality [AR] display) on map-based task performance and cognitive load. Thirty-one Soldiers from the Officer Candidate School (OCS) at Fort Benning, GA, and one Staff Sergeant participated in the study. Each Soldier completed four scenarios; one with each of the four different types of maps. Performance was evaluated based on objective performance data, data collector observations, and Soldier questionnaires. Although the 2D-NU map was preferred by the most Soldiers, generally their performance and self-reported cognitive workload ratings with the 2D-R and the 3PP maps were not significantly worse than with the 2D-NU. All four maps types offered certain advantages, depending on the situation and terrain and should be further examined in a live experiment. It is possible that all four map types should be included on an end user device (EUD) so that Soldiers can choose the map based upon the situation and their preferences or so that they can move between maps when the situation warrants.</p>					
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1. Introduction

1.1 Background

The most common way to present route instructions graphically is a geographic two-dimensional (2-D) paper map that is annotated with route information, either directly on the map or on an overlay. It provides an overview of the surroundings and is a more abstract rendering of the user's location than third-person perspective and augmented reality (AR) maps. When paper 2-D maps are used, many users rotate the maps so that the map orientation is consistent with their movement because they find the mental rotation task challenging.

Egocentric map perspectives such as the 2-D rotating map have been found to be more efficient in route-guiding situations than exocentric maps such as the north up map (Porathe, 2007; Hermann, Bieber, and Duesterhoeft, 2003). Wickens and Prevett (1995) found support for their model of aircraft displays that proposes that local guidance is better supported by more egocentric displays and the global awareness is better supported by less egocentric displays. Many users find it useful for the map to rotate into their current viewing/walking direction because they believe that this preserves their cognitive resources. They do not need to mentally or physically turn the map to be consistent with their walking direction, thus freeing their limited resources for other uses. However, this type of 2-D map may require more constant attention on the part of the user to keep the proper orientation as they navigate the terrain. Redden, Elliott, Pettitt, and Carstens (2008) found that sometimes when drivers using a rotating 2-D map looked away to perform other tasks, the map rotated because the vehicle was gradually turning and the Soldiers had difficulty reorienting and sometimes even did not realize that the map had rotated for several seconds. Seager and Stanton-Fraser (2007) found this to be true when their experiment demonstrated that users find it difficult to recognize a map that rotates automatically when they are not looking at the map.

Third-person perspective or three-dimensional (3-D) maps give a birds-eye view or view from a high position. Haberman (2005) defines such a map as a "computer-generated perspective view of a 3-D geo-data model with cartographic content." The axonometric view from these maps can make elevation differences easier for the user to understand, enhance the user's understanding of the spatial relationships between features, and create a less abstract view of the world than 2-D maps. Rakkolainen, Timmerheid, and Vainio (2000) found some evidence that people recognize landmarks and find routes in cities easier using a third-person perspective 3-D model than using a 2-D map and that search and visualization was more intuitive with 3-D. Ubiquitous applications such as Google Earth indicate the growing popularity of 3-D maps. However, they do have some problems. The scale diminishes from the front to the back of the map, making distance difficult to judge, and high topographic features can obscure adjacent lowland areas and slopes facing away from the users, depriving them of critical information.

AR systems overlay geo-spatially registered information on the user's experience of the real world. The objects in the user's surroundings become the background for computer-generated annotations that "augment" the visual field with information necessary in the performance of the current task. Azuma (1997) defines AR as a system that combines real and computer-generated information in real time and aligns virtual objects with physical ones in the environment. AR supplements reality rather than replacing it. AR can aid navigation and movement through the environment by pointing out locations in the user's field of view and by directional annotations (e.g., arrows and routes drawn on the ground). AR offers other benefits besides navigational ones. For example, AR can provide annotated information in the visual field concerning landmarks, people, or buildings seen in the environment. AR allows the user to concentrate on computer supplied information and the real world at the same time. AR might not be as efficient for planning purposes as 2-D maps because, like third-person perspective maps, topographic features can obscure adjacent lowland areas and slopes facing away from the users, depriving them of critical information. AR devices also limit planning distances to those that can be seen (line of sight and closer distances).

1.2 Objective

The goal of this study was to evaluate the cognitive load generated by four types of digital maps that have the potential for use in the augmented reality/immersive information portrayal technologies based on the end user device (EUD). The four types of maps included: a 2-D north up (2D-NU) map; a 2-D rotating (2D-R), course up map; a third-person perspective (3PP) map; and an AR display.

1.3 Overview of Experiment

This study was an investigation of the effect of the four different types of maps on map-based task performance and cognitive load. It took place at Fort Benning, GA. Thirty-one Soldiers from the Officer Candidate School (OCS) and one Staff Sergeant instructor participated in the study. After training on the simulation and the operation of the Soldier EUD and software, each Soldier completed four scenarios; one with each of the four different types of maps. The map order was counterbalanced along with the different scenarios to control for the effect of learning. Performance was evaluated based on objective performance data, data collector observations, and Soldier questionnaires.

2. Method

2.1 Participants

Thirty-two Soldiers were recruited from the OCS to participate in the study. The Soldiers included those with prior enlisted service who had a variety of backgrounds and experience levels as well as those just coming into the Army from college.

2.2 Apparatus and Instruments

2.2.1 Apparatus

2.2.1.1 Soldier End User Device Software

The Soldier user interface software employed during this user jury (v2.0.1.3) was based on the Nett Warrior EUD software that was used during the Network Integration Evaluation (NIE) 12.1. It was modified by Natick Soldier Research, Development and Engineering Center (NSRDEC) to include advanced navigation features, such as 3PP and AR. It was run using the Android Gingerbread-2.3.4 operating system on a Samsung Galaxy S II. All four types of digital mapping capabilities were integrated with this software. The display size for the phone was 4.27 in and the resolution was 480 x 800 pixels with 218 pixels per inch.

2.2.1.2 Maps

The maps used in this experiment were geographical-registered satellite images, not the typical five-color, 2-D topographic maps most associated with Soldier tasks. The first map used during this investigation (figure 1) was a standard north up digital map. Use of this 2D-NU map required the participants to mentally rotate the map or to physically turn the map to face the direction of travel. The second map was the 2D-R map (figure 2) that revolved/rotated so the direction of travel was always “up” on the screen. The third digital map (figure 3) was the 3PP map, which placed the users’ perspectives on the terrain at about a 30° angle above the ground. The fourth map (figure 4) was an AR map. To use the AR map, the users placed the EUD in the camera mode so they could see the terrain on the simulation through the display. Icons, waypoints, and other markings could be seen on top of the actual location in the simulation. For example, they could see an improvised explosive device (IED) icon directly above the IED in the simulation. All four maps were pre-loaded with operational graphics—route, checkpoints, phase lines, objective, and building labels. Additionally, the maps displayed an icon indicating the users’ positions based on simulated global positioning system (GPS) feeds. The digital 2-D maps in this study were updated as the users moved so the users’ icons were always visible. The 2D-NU did not rotate with the users. For example, if the users were traveling south, the users’ icons moved downward on the map; if the users turned right while traveling south, the icons turned left. The 2D-R rotated so that the users’ directions of travel were always facing up. The 3PP map showed more of a 3-D view than the 2-D maps and the users had a bird’s eye perspective. In this study, when the end user AR device was viewed, it showed the end user camera view with overlay labels of building numbers, chemical lights (chemlights), etc. It also showed the operational graphic for the planned route of travel.



Figure 1. 2D-NU screen shot.

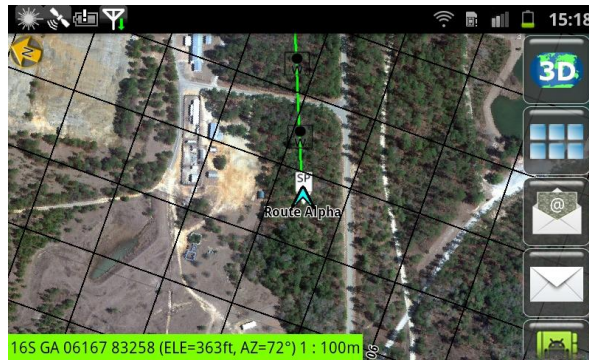


Figure 2. 2D-R screen shot.



Figure 3. 3PP screen shot.



Figure 4. AR screen shot.

2.2.2 Instruments

2.2.2.1 Simulation

The NSRDEC First Person Virtual Simulation that was used in this experiment is a portable simulation that uses digitized terrain from the McKenna Urban Training and Experimentation facility, located at Fort Benning, GA. For this experiment, it was loaded onto a standard laptop computer. The computer communicated with the Soldier's EUD via WiFi. The virtual simulation, with simulated GPS capability, allows the Soldier to move through the terrain via a joystick attached to the computer. In addition to the digitized terrain and buildings, the simulation includes vegetation, opposing forces, civilians on the battlefield and objects of interest such as IEDs. Soldier position data was logged on the EUD and plotted from the EUD files, after scenario completion, to show the Soldier's path of travel. The Soldier EUD is able to track the users' locations in the simulation and show it and their orientation on the maps. Each Soldier in the simulation plays the platoon leader in the scenario and operates as a discrete unit, operating at the Soldier's pace. Squad members are not shown in the simulation. The data collector acts as the company commander and provides periodic verbal reports and requests that drive the Soldiers' movements through the digitized terrain. Note, because this is a simulation, there are actions associated with tasks encountered in the scenarios such as "identify a contaminant" that cannot be conducted in the simulated environment (i.e., don a Chemical Biological Radiological Nuclear and Explosives suite). The simulation concentrates only on the map-based tasks.

The participants are first given an operations order that tasks them with finding: (1) a person of interest, (2) a suspected weapons cache, and (3) a chemical agent. The participants are provided a picture of the person of interest. Their digital maps provide them one of four marked routes into the McKenna facility. The participants, acting as the platoon leader in the scenario, receive orders from the company commander to mark items of interest on the routes and in the village with a digital icon and check out activities along the route and in the village. When the participants encounter civilians on the route outside of McKenna, they are required to interrogate them (for the purpose of this experiment in simulation, interrogate meant to closely view their facial features) to determine if any of them are the person of interest. When the person of interest is found, the participants report back to the company commander. One iteration of the scenario is considered to be complete once all tasks are attempted.

The Soldiers begin each of the four scenarios approximately 500 m away from McKenna Village in forested terrain and receive instructions to follow the route to McKenna (marked on the map) and report arrival at each prescribed waypoint indicated on the map. Eight civilians on the battlefield are present along the route outside of McKenna for interrogation examination regarding the person of interest. As the platoon leader reaches each check point/waypoint on the map, the platoon leader reports to the company commander whose follow-on orders drive the accomplishment of the following ten tasks.

Task 1

The company commander calls in a possible IED, giving the approximate azimuth and asks the platoon leader for confirmation of the IED. The platoon leader is told that the bursting radius of the IED is large so its location must be estimated from several meters away (just close enough to the IED to confirm its location and that it is an IED). The platoon leader then moves to the approximate IED location, identifies/confirmes the IED, and places a digital chemlight on the EUD map marking the IED location. Once the IED is marked, the platoon leader moves to the next waypoint.

- **Measure 1:** The time required to move to the IED, drop the chemlight, and move to waypoint 2.

Time begins at the end of the word “confirmation” and ends upon reaching waypoint 2 on the route after placing the chemlight on the estimated location of the IED. Time is recorded by the data collector.

- **Measure 2:** The accuracy of the chemlight location.

The system logs the position of the chemlight “dropped” by the participant on the map.

Task 2

On the route, the platoon leader encounters concertina wire and has to deviate from the route in order to navigate around the wire. The wire configuration turns the participants around several times to attempt to disorient them.

- **Measure 3:** The time required to negotiate the concertina wire and move to waypoint 3.

The data collector begins timing once the platoon leader reaches the wire and ends timing once the platoon leader arrives at the next waypoint, which is on the far side of the wire.

Task 3

The company commander calls and gives the approximate azimuth for a possible contaminant with a large danger area radius and asks the platoon leader for confirmation. The platoon leader moves to the contaminant location, locates the contaminant, places a digital chemlight on the location, and returns to the route.

- **Measure 4:** The time required to move to the contaminant, drop a chemlight and move to waypoint 4.

The data collector begins timing after the word “confirmation” and ends timing once the platoon leader reaches waypoint 4.

- **Measure 5:** The accuracy of the chemlight location.

The system logs the position of the chemlight on the map.

Task 4

Once the platoon leader reaches the route release point outside of McKenna, the platoon leader receives a call from the company commander telling the platoon leader to establish a casualty collection point (CCP) in a specified location and to mark it with a chemlight. The company commander gives a cardinal direction and a building number, i.e., southwest of building B3. This requires the platoon leader to use the graphic labels on the EUD map display.

- **Measure 6:** The location of the icon.

The system logs the position of the CPP chemlight on the map.

Task 5

The company commander calls the platoon leader and states that the team has taken casualties that need immediate care and asks the platoon leader to move to that location to provide help. The location is marked in the graphics with a “call for medic” symbol, simulating that a digital call for medic actually was transmitted.

- **Measure 7:** The time required for the platoon leader to move to the call for medic symbol.

Time begins after the location is given and ends when the platoon leader reaches the correct grid coordinates.

Task 6

The company commander calls the platoon leader and states that shots were fired by insurgents, they were seen running in a certain direction (*i.e., to NW from building C2, etc.*), and a call for fire (CFF) is needed.

- **Measure 8:** The time required for the platoon leader to place a digital chemlight where the CFF is needed.

Time begins after the words “call for fire is needed” and ends when the CFF chemlight is placed.

- **Measure 9:** The accuracy of the chemlight location.

The system logs the position of the chemlight on the map.

Task 7

The company commander calls the platoon leader saying that the person of interest has been spotted in the marketplace relative to a numbered building that is marked on the operations order map and that the platoon leader needs to move to that location and look for the person of interest.

- **Measure 10:** The time required to find the person of interest.

Time begins when the words “move to that location” are stated and ends when the person has been identified.

Task 8

The platoon leader receives a call from the company commander saying that a potential weapons cache has been found and asks the platoon leader to move to that location (*i.e., northeast corner of building x*) to confirm. The platoon leader moves to the weapons cache location and places a digital chemlight on the location upon confirming the location.

- **Measure 11:** The time required to discover the weapons cache.

Time begins when the last word of the request is given and ends when the platoon leader places the chemlight.

- **Measure 12:** The accuracy of the chemlight location.

The system logs the position of the chemlight on the map.

Task 9

The company commander calls the platoon leader saying that a potential chemical agents in two 55-gal drums located in a certain position (*i.e., southwest corner of building x*) has been found and needs confirmation. The platoon leader moves to that location, confirms the presence of the drums, and drops a chemlight symbol on the map.

- **Measure 13:** The time required to discover the suspected chemical agents (55-gal drum).

Time begins when the word “confirmation” is stated and ends when a chemlight is placed.

- **Measure 14:** The accuracy of the chemlight location.

The system logs the position of the chemlight on the map.

- **Measure 15:** The number of local nationals located out of eight along the route.

2.2.2.2 Scenarios

Four different scenarios (A-D) of equal difficulty were used during this investigation. The terrain traveled to get to McKenna and the buildings used in the scenarios were different but the tasks and the difficulties of the tasks and the distance traveled were the same.

2.2.2.3 Demographic Questionnaire

The demographic questionnaire addressed such areas as navigation experience, map reading experience, digital system experience, and physical characteristics that might have had an effect on participant’s ability to operate the interface.

2.2.2.4 Cube Comparison Test

The Cube Comparison Test (Ekstrom, French, and Harman, 1976) was used to assess participants' spatial abilities. The Cube Comparison Test requires participants to compare, in 3 min, 21 pairs of six-sided cubes and determine if the rotated cubes were the same or different.

2.2.2.5 National Aeronautics and Space Administration (NASA)-Task Load Index (TLX)

The NASA- TLX is an assessment tool that allows subjective workload assessments by operator(s) working with various human-machine systems (Hart and Staveland, 1988). It uses a multidimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six subscales. These subscales include mental demands, physical demands, temporal demands, own performance, effort, and frustration. It can be used to assess workload in various human-machine environments such as aircraft cockpits; command, control, and communication workstations; supervisory and process control environments; simulations; and laboratory tests. The version of the NASA-TLX used during this experiment was presented to the Soldiers on a computer. Definitions of each scale were provided on laminated paper so the participants could refer to it as they provided their estimates of the workload associated with each map type. The definitions are shown in table 1.

Table 1. NASA-TLX definitions and endpoints.

Title	Endpoints	Descriptions
Mental demand	Low/High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical demand	Low/High	How much physical activity was required (e.g., pushing, pulling, turning, controlling activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal demand	Low/High	How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	Low/High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

2.2.2.6 Questionnaires

The post iteration questionnaires were designed to elicit Soldiers' opinions about their performance and experiences with each of the map conditions. The questionnaires ask the Soldiers to rate their performance with the maps on a 7-point semantic differential scale ranging from "extremely good/easy" to "extremely bad/difficult." The post experiment questionnaire consisted of questions asking the participant to make comparisons between the map types and

usability questions. Usability questions cover such areas as adequacy of training, difficulty, and intuitiveness of the software, size of windows, size of icons, placement of icons, ease of placing icons, and ease of access to information.

2.3 Procedures

2.3.1 Soldier Orientation

Upon arrival, the participants received a roster number to identify them throughout the evaluation. The Soldiers were given an orientation on the purpose of the study and what their participation would involve. They were briefed on the objectives and procedures, as well as on the operator interface. They were also told how the results will be used and the benefits the military can expect from this investigation. Any questions the subjects had regarding the study were answered. The Soldiers completed an informed consent form, medical status form, and a demographics questionnaire.

2.3.2 Demographics

The participants completed a questionnaire concerning their military training and experience, including their experience with maps and global positioning systems (appendix A).

2.3.3 Cube Comparison Test

The Cube Comparison Test was administered upon completion of the demographic form.

2.3.4 Training

During training, Soldiers were given training on the operation of the simulation, on the software interface and on the EUD. Then they were issued an operations order outlining the mission. Soldiers were trained on the operation of the interface using all map configurations and were given time to practice operating the interfaces with each map type.

2.3.5 Scenario Trials

Upon completion of training, the participants completed four iterations of the scenarios, one with each map type and scenario according to the Graeco-Latin square matrix in table 2. Scenarios are labeled A, B, C, and D.

Table 2. Order of scenarios and map combinations.

Roster No.	Iteration			
	1	2	3	4
1, 5, 9, 13, 17, 21	A/2DNU	B/2DR	C/3PP	D/AR
2, 6, 10, 14, 18, 22	D/2DR	C/2DNU	B/AR	A/3PP
3, 7, 11, 15, 19, 23	B/3PP	A/AR	D/2DNU	C/2DR
4, 8, 12, 16, 20, 24	C/SAR	D/3PP	A/2DR	B/2DNU

A data collector was present with each participant to record response times (RT) and call in requests (acting as the company commander). The system logged the routes taken by the participant and the positions at which they placed the chemlights.

2.3.6 Questionnaires

Post iteration questionnaires and the NASA-TLX were administered to each Soldier at the end of each iteration corresponding to each map, and the end of experiment questionnaire was administered once all four iterations and the associated questionnaires were complete.

2.4 Experimental Design

The design of this experiment was a single factor repeated measures design.

2.4.1 Independent Variable

The independent variable was the type of map.

2.4.2 Dependent Variables

The following are the dependent variables:

- Times to complete tasks
- Accuracy of chemlight placement
- Number of local nationals located and interrogated
- Identification of the person of interest
- NASA-TLX scores
- Data collector observations
- Participant questionnaire responses

2.4.3 Predictor Variable

The predictor variable is the Cube Comparison Test.

2.5 Data Analysis

All objective data collected were analyzed using repeated measures analysis of variance (ANOVA). Follow-on pair wise comparisons were done using Holm's Bonferroni procedure to control for family-wise error rates (Holm, 1979). Partial eta squared (η^2_p), an index of effect size, was computed for each ANOVA. Iteration effects were controlled through the counterbalanced order of the experimental design. Soldier questionnaire data were analyzed using descriptive statistics on the subjective ratings.

3. Results

3.1 Demographics

The 31 participants were OCS candidates at Fort Benning, GA and one was a Staff Sergeant instructor. All had received Initial Basic Training at a minimum. The average age of the Soldiers was 26 years, and the average time in service was 19 months. Seven of the participants had previously deployed to a combat area while in the military. Twelve wore prescriptions lenses. Their self-reported experience with Army digital systems was below average and with civilian maps and GPS systems was slightly above average. Detailed responses to the demographics questionnaire are available in appendix A.

3.2 Training

Participants stated the training they received was thorough and fully prepared them to perform the tasks required to conduct the search mission in the virtual simulation.

3.3 Cube Test Results

Table 3 displays the participants' Cube Test score means that have been separated based upon the map condition they chose as the best overall condition.

Table 3. Cube Test means based upon the overall map condition preference.

Map condition	Mean number correct	SD	Number who chose this as the preferred map condition
2D-NU	8.86	5.07	21
2D-R	7.78	6.55	9
3PP	11.00	0	1
AR	3.00	0	1

3.4 Scenario Trial Results

3.4.1 Timed Data

Tables 4 through 14 show the means and standard deviations for each of the timed measures in the scenario. Also shown are the repeated measures ANOVAs results for each timed measure and the results from follow-on pair-wise comparisons subsequent to the significant ANOVAs conducted with the use of Holm's sequential Bonferroni to control for family-wise error rates.

Table 4. Measure 1. Times (sec) required to move to the IED, drop the chemlight and move to waypoint 2.

Map condition	Mean	SD
2D-NU	78	26
2D-R	73	21
3PP	81	32
AR	89	30
$F(3,93) = 1.89, p = 0.136, \eta^2_p = 0.287$		

Table 5. Measure 3. Times required negotiating the concertina wire and moving to waypoint 3.

Map condition	Mean	SD
2D-NU	71	26
2D-R	79	37
3PP	87	40
AR	109	66
$F(3,93) = 4.33, p = 0.007, \eta^2_p = 0.123$		

Table 6. Paired samples test for Measure 3.

Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
2D-NU vs. 2D-R	-1.46	31	0.16	0.025
2D-NU vs. 3PP	-1.68	31	0.10	0.017
2D-NU vs. AR	-2.79	31	0.01	0.008
2D-R vs. 3PP	<1	31	0.43	0.050
2D-R vs. AR	-1.97	31	0.06	0.013
3PP vs. AR	-2.19	31	0.04	0.010

Table 7. Measure 4. Times required to move to the contaminant, drop a chemlight and move to waypoint 4.

Map condition	Mean	SD
2D-NU	65	27
2D-R	66	24
3PP	75	33
AR	96	55
$F(3,93) = 5.59, p = 0.001, \eta^2_p = 0.153$		

Table 8. Paired samples test for Measure 4.

Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
2D-NU vs. 2D-R	<1	31	0.85	0.050
2D-NU vs. 3PP	-1.71	31	0.10	0.017
2D-NU vs. AR	-3.53 ^a	31	<0.001	0.008
2D-R vs. 3PP	-1.15	31	0.26	0.025
2D-R vs. AR	-2.92 ^a	31	0.01	0.010
3PP vs. AR	-1.83	31	0.08	0.013

^a $p < 0.05$, 2-tailed.

Table 9. Measure 7. Times required for the platoon leader to move to the call for medic symbol.

Map condition	Mean	SD
2D-NU	37	14
2D-R	41	20
3PP	42	18
AR	56	23
$F(3,93) = 5.81, p = 0.001, \eta^2_p = 0.158$		

Table 10. Paired samples test for Measure 7.

Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
2D-NU vs. 2D-R	<1	31	0.34	0.025
2D-NU vs. 3PP	-1.29	31	0.21	0.017
2D-NU vs. AR	-3.67*	31	<0.001	0.008
2D-R vs. 3PP	<1	31	0.87	0.050
2D-R vs. AR	-2.66*	31	0.01	0.013
3PP vs. AR	-2.84*	31	0.01	0.010

* $p < 0.05$, 2-tailed.

Table 11. Measure 8. Times required for the platoon leader to place a digital chemlight where the CFF is needed.

Map condition	Mean	SD
2D-NU	48	23
2D-R	57	40
3PP	50	40
AR	68	43
$F(3,93) = 1.88, p = 0.138, \eta^2_p = 0.057$		

Table 12. Measure 10. Times required to find the person of interest.

Map condition	Mean	SD
2D-NU	35	22
2D-R	39	22
3PP	36	25
AR	41	19
$F < 1$		

Table 13. Measure 11. Times required to discover the weapons cache.

Map condition	Mean	SD
2D-NU	41	42
2D-R	37	34
3PP	42	46
AR	59	65
$F(3,90) = 1.14, p = 0.335, \eta^2_p = 0.037$		

Table 14. Measure 13. The time required to discover the suspected chemical agents (55-gal drums).

Map condition	Mean	SD
2D-NU	23	15
2D-R	24	21
3PP	25	19
AR	32	27
$F(3,93) = 1.24, p = 0.299, \eta^2_p = 0.038$		

The participants took more time using the AR map on every measure (figure 5). Three of the measures showed that they were significantly slower with AR map than they were with the 2D-NU map and on those measures, the comparisons between the AR map and the 2D-R and 3PP maps were either significant or they approached significance. Although the 2D-NU map was quickest on all timed measures but two, there were no significant differences found on any of the timed measures between the 2D-NU, 2D-R, and 3PP maps.

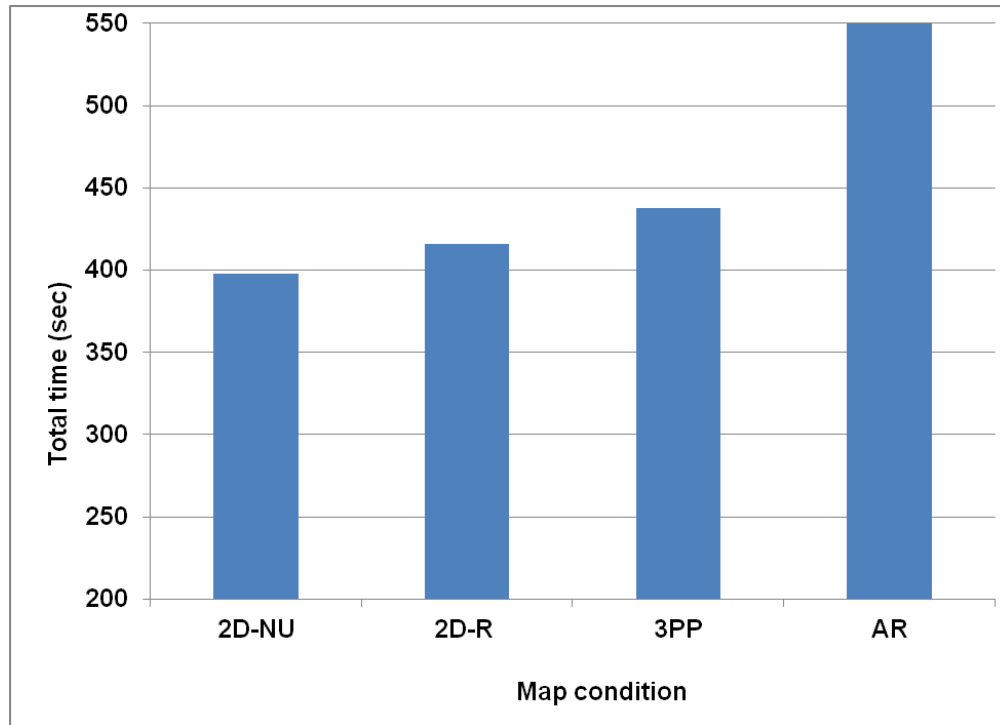


Figure 5. Total task times.

3.4.2 Accuracy Measure Results

Tables 15–26 display the accuracy measures taken when the participants were required to place a chemlight on a specific location.

Table 15. Measure 2. Distance (meters) of chemlight from the IED.

Map condition	Mean	SD
2D-NU	18.1	10.6
2D-R	18.5	10.4
3PP	17.6	10.4
AR	33.4	32.3
$F(3,90) = 5.37, p = 0.002, \eta^2_p = 0.152$		

Table 16. Paired samples test for Measure 2.

Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
2D-NU vs. 2D-R	<1	31	0.84	0.025
2D-NU vs. 3PP	<1	31	0.84	0.050
2D-NU vs. AR	-2.54	31	0.02	0.008
2D-R vs. 3PP	<1	31	0.68	0.017
2D-R vs. AR	-2.44	31	0.02	0.010
3PP vs. AR	-2.47	31	0.02	0.013

Table 17. Measure 5. Distance of chemlight from contaminant.

Map condition	Mean	SD
2D-NU	20.2	12.5
2D-R	20.8	10.5
3PP	15.0	8.4
AR	24.2	18.0
$F(3,87) = 2.68, p = 0.05, \eta^2_p = 0.09$		

Table 18. Paired samples test for Measure 5.

Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
2D-NU vs. 2D-R	<1	31	0.76	0.050
2D-NU vs. 3PP	2.16	31	0.06	0.013
2D-NU vs. AR	<1	31	0.36	0.017
2D-R vs. 3PP	2.49	31	0.02	0.008
2D-R vs. AR	<1	31	0.43	0.025
3PP vs. AR	-2.44	31	0.02	0.010

Table 19. Measure 6. Percent of participants who correctly placed the chemlight in the vicinity of the CCP.

Map condition	Mean	SD
2D-NU	84	37
2D-R	78	42
3PP	47	51
AR	3	17
$F(3,93) = 29.87, p < 0.001, \eta^2_p = 0.49$		

Table 20. Paired samples test for Measure 6.

Pair	<i>t</i>	df	<i>obtained p</i>	<i>required p</i>
2D-NU vs. 2D-R	<1	31	0.54	0.050
2D-NU vs. 3PP	3.22 ^a	31	<0.001	0.017
2D-NU vs. AR	9.76 ^a	31	<0.001	0.008
2D-R vs. 3PP	2.99 ^a	31	0.01	0.025
2D-R vs. AR	9.64 ^a	31	<.0001	0.010
3PP vs. AR	4.91 ^a	31	<0.001	0.013

^a $p < 0.05$, 2-tailed.

Table 21. Measure 9. Distance from the chemlight placement to the CFF.

Map condition	Mean	SD
2D-NU	55.9	29.1
2D-R	56.2	27.5
3PP	48.1	26.9
AR	149.2	169.9
$F(3,93) = 9.46, p < 0.001, \eta^2_p = 0.234$		

Table 22. Paired samples test for Measure 9.

Pair	<i>t</i>	df	<i>obtained p</i>	<i>required p</i>
2D-NU vs. 2D-R	<1	31	0.97	0.050
2D-NU vs. 3PP	<1	31	0.33	0.025
2D-NU vs. AR	-3.16 ^a	31	0.01	0.010
2D-R vs. 3PP	1.40	31	0.17	0.017
2D-R vs. AR	-2.96 ^a	31	0.01	0.013
3PP vs. AR	-3.34 ^a	31	< 0.001	0.008

^a $p < 0.05$, 2-tailed.

Table 23. Measure 12. Distance from the chemlight to the weapons cache.

Map condition	Mean	SD
2D-NU	9.1	4.4
2D-R	8.7	3.7
3PP	9.1	4.8
AR	45.6	38.4
$F(3,93) = 28.41, p < 0.001, \eta^2_p = 0.478$		

Table 24. Paired samples test for Measure 12.

Pair	<i>t</i>	df	<i>obtained p</i>	<i>required p</i>
2D-NU vs. 2D-R	<1	31	0.69	0.017
2D-NU vs. 3PP	<1	31	0.99	0.050
2D-NU vs. AR	-5.25 ^a	31	<0.001	0.013
2D-R vs. 3PP	<1	31	0.74	0.025
2D-R vs. AR	-5.47 ^a	31	<0.001	0.008
3PP vs. AR	-5.46 ^a	31	<0.001	0.010

^a $p < 0.05$, 2-tailed.

Table 25. Measure 14. Distance from the chemlight location to the 55-gal drums.

Map condition	Mean	SD
2D-NU	9.4	4.6
2D-R	9.2	3.0
3PP	9.5	4.4
AR	27.0	20.0
$F(3,90) = 21.99, p < 0.001, \eta^2_p = 0.423$		

Table 26. Paired samples test for Measure 14.

Pair	<i>t</i>	df	<i>obtained p</i>	<i>required p</i>
2D-NU vs. 2D-R	<1	31	0.82	0.025
2D-NU vs. 3PP	<1	31	0.90	0.050
2D-NU vs. AR	-4.61 ^a	31	<0.001	0.013
2D-R vs. 3PP	<1	31	0.73	0.017
2D-R vs. AR	-4.89 ^a	31	<.001	0.010
3PP vs. AR	-4.99 ^a	31	<0.001	0.008

^a $p < 0.05$, 2-tailed.

Figure 6 shows the average distance from the target that the chemlights were placed in each map condition for all the accuracy measures.

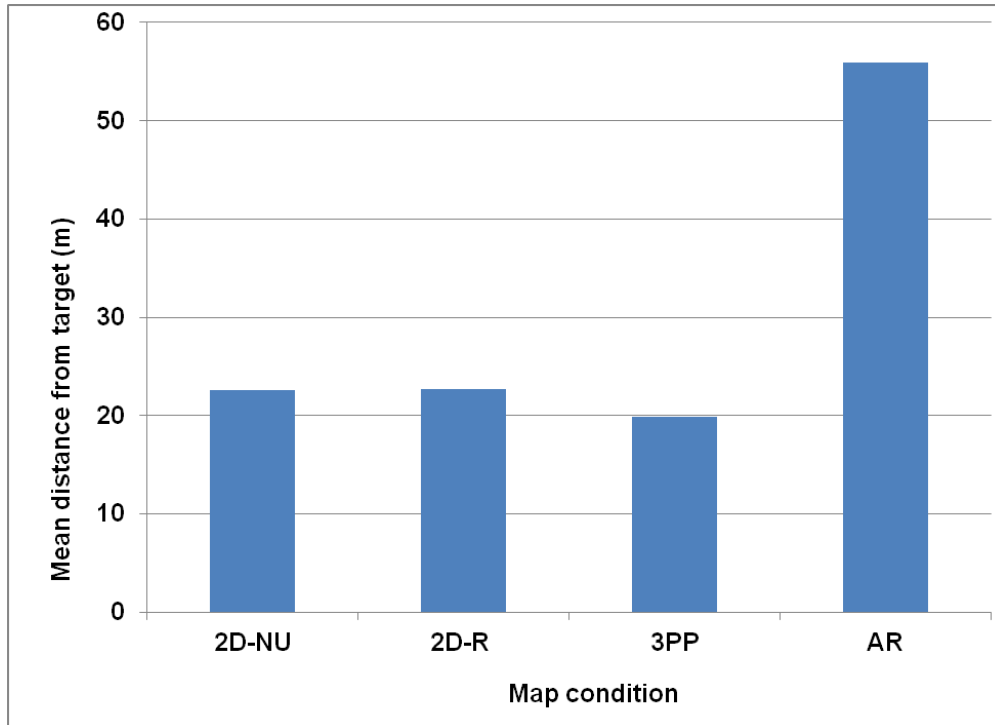


Figure 6. Mean distance from target, chemlight placement.

Tables 27 and 28 display the findings from the evaluation of the local nationals found along the route. There were only eight local nationals and somewhat of a ceiling effect was found. Despite this ceiling effect, significantly fewer local nationals were found when the AR map was used.

Table 27. Measure 15. Number of local nationals found (out of eight).

Map condition	Mean	SD
2D-NU	7.88	0.94
2D-R	7.88	0.91
3PP	7.59	1.16
AR	7.28	1.25
$F(3,93) = 4.087, p = 0.009, \eta^2_p = 0.116$		

Table 28. Paired samples test for Measure 15.

Pair	<i>t</i>	df	<i>obtained p</i>	<i>required p</i>
2D-NU vs. 2D-R	<1	31	0.99	0.050
2D-NU vs. 3PP	1.55	31	0.13	0.017
2D-NU vs. AR	2.83 ^a	31	0.01	0.008
2D-R vs. 3PP	1.72	31	0.1	0.013
2D-R vs. AR	2.77 ^a	31	0.01	0.010
3PP vs. AR	1.22	31	0.23	0.025

^a $p < 0.05$, 2-tailed.

3.5 NASA-TLX Results

Table 29 and figure 7 show the mean ratings on the NASA-TLX subscales and total workload scale for each of the map conditions.

Table 29. NASA TLX means and SDs (in parentheses).

Scale	2D-NU	2D-R	3PP	AR
Mental	37.8 (20.6)	39.1 (22.4)	45.6 (22.8)	53.6 (21.1)
Physical	19.7 (16.9)	20.8 (19.9)	21.6 (18.1)	27.0 (24.4)
Temporal	34.2 (21.6)	35.8 (24.8)	35.2 (21.2)	47.2 (25.5)
Performance	34.8 (28.6)	35.3 (29.3)	41.9 (25.0)	54.1 (23.4)
Effort	35.6 (22.0)	36.6 (22.3)	46.6 (21.5)	56.3 (24.0)
Frustration	23.6 (20.2)	26.1 (23.0)	35.0 (23.3)	56.4 (29.4)
Total workload	36.3 (19.0)	36.6 (19.8)	43.9 (18.9)	55.0 (18.8)

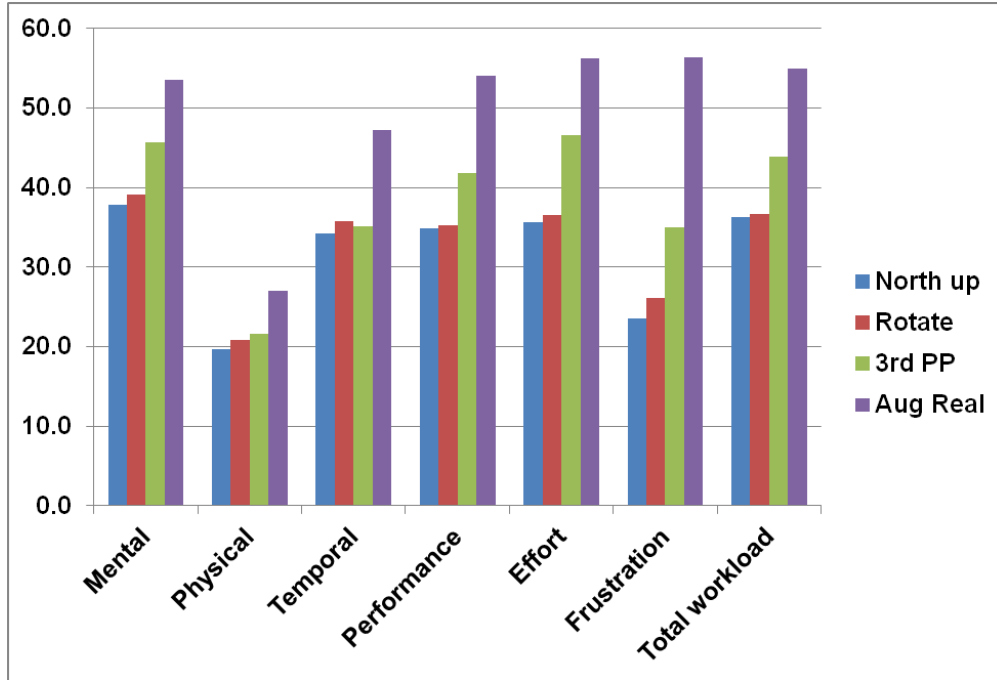


Figure 7. NASA TLX means.

Repeated measures ANOVA (table 30) indicate that there were significant differences among the means on every scale except physical workload.

Table 30. Summary of NASA-TLX ANOVAs.

Scale	<i>F</i>	df	<i>p</i>	η^2_p
Mental	8.1 ^a	3,93	< 0.01	0.21
Physical	2.29	3,93	0.08	0.07
Temporal	4.24 ^a	3,93	0.01	0.12
Performance	5.11 ^a	3,93	<0.01	0.14
Effort	10.6 ^a	3,93	< 0.01	0.256
Frustration	17.1 ^a	3,93	< 0.01	0.355
Total	11.2 ^a	3,93	< 0.01	0.266

^a $p < 0.01$

Follow-on paired comparisons were conducted using Holm's Bonferroni correction for family-wise error rates. The paired comparisons are summarized in table 31.

Table 31. Follow-on paired comparisons, NASA-TLX.

<i>Mental:</i>				
Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
NU vs. Rot	< 1	31		
NU vs. 3rd PP	2.67 ^a	31	0.012	0.013
NU vs. AR	4.24 ^a	31	0.001	0.008
Rot vs. 3rd PP	1.74	31	0.092	0.025
Rot vs. AR	3.47 ^a	31	0.002	0.010
3rd PP vs. AR	2.10	31	0.044	0.017

<i>Temporal:</i>				
Pair	<i>T</i>	df	obtained <i>p</i>	required <i>p</i>
NU vs. Rot	< 1	31		
NU vs. 3rd PP	< 1	31		
NU vs. AR	2.55	31	0.016	0.010
Rot vs. 3rd PP	< 1	31		
Rot vs. AR	2.18	31	0.037	0.013
3rd PP vs. AR	2.77	31	0.009	0.008

<i>Performance:</i>				
Pair	<i>T</i>	df	obtained <i>p</i>	required <i>p</i>
NU vs. Rot	< 1	31		
NU vs. 3rd PP	1.57	31	0.126	0.017
NU vs. AR	2.76	31	0.010	0.008
Rot vs. 3rd PP	1.48	31	0.150	0.025
Rot vs. AR	2.69	31	0.011	0.010
3rd PP vs. AR	2.21	31	0.034	0.013

<i>Effort:</i>				
Pair	<i>T</i>	df	obtained <i>p</i>	required <i>p</i>
NU vs. Rot	< 1	31		
NU vs. 3rd PP	2.83 ^a	31	0.008	0.013
NU vs. AR	4.14 ^a	31	< 0.001	0.010
Rot vs. 3rd PP	2.56 ^a	31	0.015	0.017
Rot vs. AR	4.25 ^a	31	< 0.001	0.008
3rd PP vs. AR	2.22	31	0.034	0.025

<i>Frustration:</i>				
Pair	<i>t</i>	df	obtained <i>p</i>	required <i>p</i>
NU vs. Rot	< 1	31		
NU vs. 3rd PP	2.82 ^a	31	0.008	0.017
NU vs. AR	5.72 ^a	31	< 0.001	0.008
Rot vs. 3rd PP	2.33	31	0.033	0.025
Rot vs. AR	4.48 ^a	31	< 0.001	0.010
3rd PP vs. AR	3.96 ^a	31	< 0.001	0.013

<i>Total workload:</i>				
Pair	<i>T</i>	df	obtained <i>p</i>	required <i>p</i>
NU vs. Rot	< 1	31		
NU vs. 3rd PP	2.76 ^a	31	0.010	0.013
NU vs. AR	4.35 ^a	31	< 0.001	0.008
Rot vs. 3rd PP	2.29	31	0.029	0.025
Rot vs. AR	3.93 ^a	31	< 0.001	0.010
3rd PP vs. AR	2.73 ^a	31	0.010	0.017

^a $p < 0.05$, 2-tailed.

The 2D-NU and 2D-R map conditions were not significantly different on any of the subscales or on total workload. The workload ratings for the 2D-NU and 2D-R maps were lower than the

ratings for AR on the mental, performance, effort, frustration, and total workload scales. Average workload ratings for the 2D-NU map were lower than the mean ratings for 3PP map on the mental, effort, frustration, and total workload scales. The 2D-R and 3PP maps were significantly different on the effort, frustration, and total workload scales (the 2D-R map workload was lower on all). Mean ratings for the 3PP map were significantly lower than the mean AR ratings on the temporal, effort, frustration, and total workload scales.

In summary, workload ratings were lowest for the 2D-NU and 2D-R map, intermediate for the 3PP map, and highest for the AR map.

3.6 Questionnaire Results

3.6.1 Post Iteration Questionnaire Results

The 2D-NU map was rated highest for keeping track of one's orientation. Some Soldiers reported difficulty determining in which direction to move once a cardinal direction was given by the platoon leader when using the 2D-R map because they had to first determine their current orientation, and then translate it in their heads. However, their performance times did not significantly reflect this stated difficulty (see the 2D-R times in tables 10 and 13). These Soldiers also reported that they had to constantly monitor the rotating map so they did not become confused when it rotated. Other Soldiers found the rotating map easy to use and very similar to the map in their GPSs.

A few Soldiers indicated that the size of the EUD was a little too small to differentiate between buildings in the village and that it was difficult to precisely drop a chemlight on the intended position because the display area was so small in relation to the size of their fingers. They suggested that they needed to be able to zoom in closer to accurately place the chemlights with their "fat" fingers. They reported some difficulty with placing chemlights on areas at distances from their current location with all four map types; however, this was likely an artifact from using a simulation, because many of the distance estimation cues available in a natural environment were not available in the simulation (i.e., accommodation and convergence at close distances, binocular disparity, aerial perspective, etc.). They rated accurately placing a chemlight on a remote location as being more difficult with the 3PP and AR maps than with the 2-D maps. Soldiers reported that the chemlight "shifted" in the 3PP map mode and that it seemed to fall in a different location than they intended. Dropping a chemlight in an accurate location was also reported to be difficult in the AR map mode. One Soldier suggested that it would be beneficial to use the crosshairs on the eyepiece to accurately place chemlights.

Estimating distance, following a pre-drawn route, and the projected ease of planning a route was rated as more difficult with the AR map than with the other three map types. One Soldier suggested adding two indicators in the corner of the AR map screen would help with following a pre-drawn route. The first would always point in the direction of the route and the other would point to the waypoint. These would help the Soldier return to the route if the Soldier got off the

route and could not find it and orient toward the waypoint. Some Soldiers complained that the “lollipop” stick building markers, which were used in the AR mode, did not actually mark the buildings that were intended. Others complained that the screen became so cluttered with markers that it was difficult to determine what was being marked, see all the information on the screen, and add markers in the same area. One suggestion was to make the markers translucent and allow the user to change their sizes if needed.

Detailed comments from the post iteration questionnaire can be found in appendix B.

3.6.2 End of Experiment Questionnaire Results

The end of experiment questionnaire asked the Soldiers to choose the map they preferred for several map-based tasks. Table 32 displays their choices.

Table 32. Number of Soldiers choosing each map type as best for map-based tasks.

Tasks	Number of Responses ^a			
	2D-NU	2D-R	3PP	AR
Best for dropping a chemlight on a given grid coordinate	19	11	1	2
Best for dropping a chemlight on the map to show the location of an object off your path	14	13	2	3
Best for estimating distance	15	10	6	2
Best for following a pre-drawn route	17	12	2	3
Best for keeping track of your orientation	24	6	2	1
Best for determining which building you are facing	17	8	5	2
Best for determining the best way to go around an obstacle on the route	20	7	0	2
Best for finding the location of a chemlight that is marked on the map	14	13	3	6
Most intuitive (i.e., easy to use/understand without much training)	22	10	1	0
Best for ease of engaging touch options	22	11	2	1
Best for ease of enlarging map	19	14	3	7
Best for ease of moving map in north, south, east, or west directions	19	13	2	1
Best for ease of zooming in and out	21	14	0	0

^aTotal number of responses may exceed N as some participants chose more than one map.

While the 2D-NU map was chosen as best by the most Soldiers for each map-based task, some of the Soldiers preferred other map types for the majority of the tasks and many other Soldiers chose different types of maps, depending on the task. For example, some of the Soldiers preferred a rotating map so that they did not have to mentally rotate the 2D-NU in their heads. One Soldier commented that the 3PP map would have been more useful in mountainous terrain. Another pointed out that a combination of one of the 2-D maps with the AR would work well because with an AR map it was easier to identify buildings/objects but a 2-D map works well in providing an overall view of the area.

Many Soldiers saw potential in the AR mode but felt that more work is needed to make it practical to use. Overall, the 2D-NU appeared to create the lightest cognitive load. It made it easy to keep track of orientation and made it easy to determine the orientation of fixed objects such as buildings.

Table 33 lists some of the most notable suggested improvements to an EUD map.

Table 33. Suggested improvements to the map systems.

Suggestion	No. of Responses
Make the AR map building markers transparent or make them only pop up on demand.	2
Provide the ability to highlight or point to objects on screen and compute my distance from the point.	2
Provide a small stylus for more precision.	2
Provide more resolution.	2
Enlarge the screen.	1
Provide the ability to zoom in more closely.	1
Provide zoom in the AR mode.	1
Provide real-time imagery so that current barriers and changes can be seen.	1
Provide location from which shots have been fired.	1
Provide location and direction of enemy movement.	1
Decrease lag time.	1
Provide the ability to drop a symbol at current location.	1

Detailed responses to the end of experiment questionnaire are available in appendix C.

3.6.3 Experiment Limitations and Experimenter Observations

3.6.3.1 Route Planning and Movement in the Simulation

An important function of a map is to give the Soldier necessary information to plan a route for dismounted movement. Typical military maps portray information related to distance, contour, natural obstacles, and manmade structures. Before movement, a Soldier in the field would routinely perform a map reconnaissance and select routes (primary and alternate) that would provide the necessary speed, cover and concealment, and security as required by the mission. We anticipated that the Soldiers would find that the four Information Portrayal Levels (2D-NU, 2D-R, 3PP, and AR) would provide a spectrum of capability with respect to route planning. However, in planning the execution of this experiment in the virtual simulation, we removed this responsibility from the Soldier. To control the pace of the experiment and allow for comparisons of movement times between the four different Information Portrayal Levels, we provided a preplanned route in the operational graphics loaded on the Soldier's EUD. Therefore, all the Soldier was required to do was grab the joystick and move along the route without thought to proper route planning considerations. A limitation of the simulation was that there was no penalty to the Soldier for making bad navigational choices. The Soldier could walk through trees, walk backwards for extended periods, and move with no regard for security. A more

realistic approach would be to conduct a similar experiment live in the field and allow (require) the Soldier to plan a reasonable route prior to movement.

Another artifact of movement in the simulation, versus in a live environment, was the speed at which the Soldiers were able to move. Originally, the scenarios were planned to last about 1 h each from the start point to the completion of the scenario in the MOUT site. In practice, each scenario only lasted about 15 min. This was likely due to a last-minute software change in the joystick driver. Soldiers were able to move through the scenario too quickly. This caused elapsed times for the measures of performance to be less distinctive from each other. Again, the next best experiment would be to conduct a similar event in the field where realistic movement rates would be imposed by the natural terrain.

3.6.3.2 No Established Standard for Time or Accuracy

It is important to note that there was no established standard for each of the performance measures involving time and chemlight location accuracy. The results for each Information Portrayal Level are intended to be compared with each other. An interesting, but not necessarily essential, experiment would be to run similar scenarios in the field with legacy systems, i.e., map, compass, and precision lightweight GPS receiver (PLGR), for example, and establish baseline standards for each of the measures. Interested stakeholders could then assess these new Information Portrayal Levels against systems currently in the field.

3.6.3.3 Augmented Reality in the Standalone Mode

For the purpose of this experiment, the Soldiers were required to use only one Information Portrayal Level per scenario to allow for comparisons. This is an unlikely operational restriction. When such systems are actually fielded to Soldiers, it is most likely that they will be able to switch back and forth between modes to use the mode most suitable to their current operational situation. Alternately, they may have multiple systems that give them more than one capability at the same time. This is most true for the AR mode. As run in this experiment, the Soldier had no access to a map of any kind during the scenario using the AR mode. The Soldier's only terrain knowledge came from what Soldiers could see in their field of view on the video monitor. The operational graphics associated with that scenario were only visible to the Soldier when the Soldier maneuvered into the vicinity of the graphic. Operationally, a Soldier responsible for movement, planning routes, and reacting to operational graphics would always have an accompanying map, either paper or digital, with the necessary information available for viewing. So, another way to assess with AR mode would be to allow the Soldier capability to switch back and forth from AR mode to one of the map modes, or provide an additional map that could be referenced when necessary. This should be a planning consideration for subsequent studies.

3.6.3.4 Chemlight Task

We encountered a perplexing phenomenon during the experiment. Each scenario followed a written script that was managed by an Observer Controller (OC) sitting one-on-one, elbow-to-

elbow with each Soldier. The OC, acting as the Soldier's company commander, would communicate tactical instructions from the detailed script to the Soldier to control the action. The OC told the Soldier when to move, when to report, what to report, and where to drop what type and color chemlights. Upon collecting the data from the EUD at the end of the scenario, we found numerous errors in the color and type of chemlights that were dropped in the execution of each task. There was no penalty assessed for the incorrect chemlight type or color. Based on location and sequence in the script, we could determine the correct chemlight type and color and assign the correct value for assessment of the performance measure. We recommend that in subsequent studies that we grade the Soldiers after one or more practice scenarios and we impose a penalty for not following the commander's instructions precisely.

4. Discussion and Recommendations

Soldiers found some difficulty in using the small (4.27-in) touch screen on the smart phone. Their fingers were too large to accurately drop the chemlights in the intended location, especially in high density areas such as McKenna. Three approaches or combinations of approaches to fix this problem should be investigated. The first approach is to allow them to zoom farther in so that the area covered by their fingers is smaller. The second approach is to provide a stylus with a fine point so that it covers a smaller area than the fingers. The stylus would have to be attached via a lanyard so that it does not become lost. The third approach is to put the software on a tablet with a display size of 7 to 10 in, rather than a phone so that the entire scene can be easily seen without zooming and so that the finger covers a smaller area. However, this approach is not without cost because it has adverse implications on the weight and bulk of the Soldiers' loads.

Findings from this experiment did not support Wickens and Prevett's (1995) model of aviation navigation in terms of the egocentric (2D-R) display providing better support for local guidance and Wicken's (1999) evidence for performance costs associated with navigational tasks with an exocentric viewpoint (i.e., mental rotation of a north-up map when heading south). In fact, one of the tasks which Soldiers reported to require mental rotation was trying to determine the north corner of the building when using the 2D-R map because they had to determine their heading direction from the phone and then mentally rotate the building to find which corner was north. However, these findings might have been affected by the scenarios used. Most of the travel was in the north, northeast, and northwest directions and did not require mental rotation of the north up map. Thus, a decision not to use the 2D-R map might be premature. Also, although the rotating 2D-R map was only preferred by 9 of 32 Soldiers, most of today's automotive navigational maps can rotate with the vehicle. As automotive navigational maps become more common, more Soldiers of the future may enter the Army with a high degree of familiarity with this rotating map, and may be less inclined toward the fixed north up map.

Haskell and Wickens (1993) found that 2-D displays and perspective displays had different strengths and weaknesses for aircraft navigation, and this may be the case for land navigation. The perspective display fostered superior lateral and altitude flight-path tracking accuracy, and the 2-D display fostered superior airspeed tracking accuracy. Because the terrain used in this simulation was relatively flat, the possible strengths of the 3PP display were not examined in this experiment. Soldiers entering unfamiliar territory must rely on the map display to build spatial awareness. A digital 2-D map that uses satellite imagery does not provide contour lines so that they can reconstruct the 3-D nature of the area in which they will operate. Perspective displays can depict all three dimensions of the space, without requiring Soldiers to integrate textual and spatial information like they have to if they use maps with contour lines. It may be that Soldiers only want to look at a 3PP displays for specific tasks and it might be important to provide the 3PP display for use only on these tasks.

The labels on the AR map created high clutter in the McKenna area. Suggested improvements to this problem include making the label markers transparent, having the markers show only on the fixed objects (buildings) that can be seen with line of sight and requiring the Soldier to request markers for objects not seen in line of sight, or even a combination of these suggestions. The AR labels in this simulation were not always on the correct objects. Geospatial registration accuracy must be high for an AR map to be effective. Labels that are off by even 1 m can cause confusion or worse. Also, it became apparent during this experimentation that AR augments a map but does not replace it because it does not provide adequate global awareness of the area. However, further experimentation is needed before taking AR out of consideration. The use of the AR map in a simulation may have created more problems than would be experienced in a real-world situation. Holding the smart phone up to the eye to see the simulation through the phone's camera was difficult and placing chemlights in the AR mode was extremely difficult with this method

5. Conclusions

In this experiment, the 2D-NU map was preferred by the most Soldiers. However, generally their performance with the 2D-R and the 3PP maps was not significantly worse than with the 2D-NU. There was no significant difference in self-reported cognitive workload ratings between the 2D-NU and the 2D-R. The 2D-NU and 2D-R map mental workload ratings were significantly lower than those of the AR map, and the 2D-NU map mental workload ratings were significantly lower than for the 3PP map. All four maps types offered certain advantages, depending on the situation and terrain. They should be further examined in a live experiment that contains terrain that could demonstrate their advantages before they are removed from consideration. It is possible that all four map types should be included on an EUD so that Soldiers can choose the

map based upon the situation and their preferences or so that they can move between maps when the situation warrants.

There were three limitations in this experiment that were based upon the terrain and the simulation that may have adversely affected opinions and performance with the 2D-R, 3PP, and AR maps. First, the terrain around the McKenna site was not conducive to approaches from the north. Approaches from the north would have required the Soldiers to use more of their cognitive resources to mentally rotate the 2D-NU map and show the advantage of the 2D-R map. For example, if Soldiers were traveling north and wanted to turn east it would be easy to see that a right turn was needed. However, if Soldiers were traveling south and wanted to turn east, they would have to mentally rotate the map to determine that they need to turn left. Second, the terrain used was relatively flat and did not show the advantage the 3PP map may have experienced in mountainous or hilly terrain. Third, use of the AR map in a simulation may have created more problems than would be experienced in a real-world situation. This experiment was only a first step in examining the four map types. It is recommended that all four map types be examined further in a live environment that does not contain the limitations mentioned above.

6. References

- Azuma, R. T. A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments* **1997**, 6 (4), 355–385.
- Ekstrom, R. B.; French, J. W.; Harman, H.; Derman, D. *Kit of Factor-referenced Cognitive Tests* (rev. ed.); Princeton, NJ: Educational Testing Service, 1976.
- Haberlind, C. Cartographic Design Principles for 3E Maps: A Contribution to Cartographic Theory. *Proceedings of the 22nd ICA International Cartographic conference*, A Coruna, Spain, 2005.
- Hermann, F.; Bieber, G.; Duesterhoeft, A. Egocentric Maps on Mobile Devices. *In the Proc. International Workshop on Mobile Computing*, 2003.
- Holms, S. A. A Simple Sequentially Rejective Multiple Test Procedure. *Scandinavian Journal of Statistics* **1979**, 6 (2), 65–70.
- Porathe, T. User-centered Map Design. *In UPA 2007 Conference Patterns: Blueprints for Usability*, Austin, Texas, June 11–15, 2007.
- Rakkolainen, I.; Timmerheid, J.; Vainio, T. A 3D City Info for Mobile Users. *Proceedings of the 3rd International Workshop in Intelligent Interactive Assistance and Mobile Multimedia Computing (IMC'2000)*, November 9–10, 2000, Rockstock, Germany, 115–212.
- Redden, E. S.; Elliott, L. R.; Pettitt, R. A.; Carstens, C. B. A Tactile Option to Reduce Robot Controller Size. *Journal on Multimodal User Interfaces* **2008**, 2, 205–216.
<http://www.springer.com/computer/user+interfaces/journal/12193>
- Schobesberger, D.; Patterson, T. Evaluating the Effectiveness of 2D vs. 3D Trailhead Maps. Zion National Park, U.S., 2007.
- Seager, W.; Stanton-Fraser, D. Comparing Physical, Automatic and Manual Map Rotation for Pedestrian Navigation. *In ACM SIGCHI Conference on Computer-Human Interaction (CHI 2007)*, ACM Press, May 2007, pp 767–776.
- Wickens, C. D. Frames of Reference for Navigation. In Daniel Gopher and Asher Koriati (eds) *Attention and Performance XVII: Cognitive Regulation of Performance: Interaction of Theory and Application*. Attention and Performance (pp. 113–144). Cambridge, MA, US: The MIT Press, xiii, 814 pp, 1999.
- Wickens, C. D.; Preveit, T. T. Exploring the Dimension of Egocentricity in Aircraft Navigation Displays. *Journal of Experimental Psychology: Applied* **1995**, 2, 110–136.

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Appendix A. Demographic Information

DEMOGRAPHICS

SAMPLE SIZE = 32

<u>MOS</u>	<u>RANK</u>	<u>DUTY POSITION</u>	<u>AGE</u>
09S – 22 15W – 1	OCS - 31	Officer Candidates - 31	26 years (mean)
11B – 1 36B – 1	E6 – 1	Instructor – 1	
13D – 1 37F – 1			
13F – 1 NR – 3			
15R – 1			

1. What is your height? 71 inches (mean) – Range is 66 to 80 inches.
2. What is your weight? 177 pounds (mean) – Range is 138 to 240 pounds.
3. How long have you served in the military? 19 months (mean)
4. Have you been deployed in a hostile fire zone? 25 No 5 Yes 2 NR

If yes, how many deployments to each combat area?

Bosnia 0 # of deployments 0 months

Iraq 6 # of deployments 78 months

Afghanistan 1 # of deployments 12 months

5. With which hand do you most often write? 28 Right 4 Left
6. With which hand do you most often fire a weapon? 27 Right 5 Left
- 7.a. Do you wear prescription lenses? 20 No 12 Yes
 - b. If yes, which? 5 Glasses 6 Contacts 1 Both
8. Which of the following military training have you received?

Number of Responses			
32	Basic Training	1	One Station Unit Training
5	Warrior Leader's course	2	Airborne
1	Advance Leader's course	0	Senior Leader's course
0	Ranger	12	Combat Life Saver
0	Master Gunner	5	Other: armorer, landscaping

9. Using the scale below, rate your level of experience with the following computer software and computer related activities.

1	2	3	4	5	6	7
No experience	Below Average	Slightly below average	Average	Slightly above average	Above average	Expert

	MEAN
Microsoft Windows 98, 2000, XP, etc.	5.29
Computer based games	4.69
Internet	5.38
AKO	4.06
My Pay	4.13
Smart phone	4.91
Army digital systems (e.g. FBCB2)	1.81
I would self rate my computer skills as:	4.97

10. Using the scale below rate your level of experience with the following map based devices and location aids.

1	2	3	4	5	6	7
No experience	Below Average	Slightly below average	Average	Slightly above average	Above average	Expert

	MEAN
Military topographic maps	4.09
Civilian paper maps	4.47
Civilian Global Positioning Systems (GPSs)	4.84
Military GPSs (PLGR, etc.)	2.06
Google Earth	4.47
Computer based mapping products (Mapquest, etc.)	4.91
Military Grid Reference System	3.28
Latitude/Longitude system	3.50
Knowledge of infantry tactics, techniques, and procedures (TTP)	2.81
Smartphone based maps	3.97
Other:	3.25

Appendix B. Post Iteration Questionnaire Results

POST ITERATION

SAMPLE SIZE = 32

Maps	2D North up map	2D-NU
	2D Rotating map	2D-R
	3rd Person perspective map	3PP
	Augmented reality map	AR

1. Using the scale below, please rate the map that you just used for the following tasks.

1 2 3 4 5 6 7
 Extremely bad Very bad Bad Neutral Good Very good Extremely good

TASKS	MEAN			
	2D-NU	2D-R	3PP	AR
Dropping a chemlight on a given grid coordinate	5.85	5.90	4.27	4.00
Dropping a chemlight on the map to show the location of an object off your path	5.91	5.78	4.31	4.00
Estimating distance	5.09	5.00	4.94	3.78
Following a pre-drawn route	6.19	6.22	5.97	4.41
Keeping track of your orientation	6.31	5.28	5.44	4.00
Determining which building you are facing	5.50	5.56	5.19	3.78
Determining the best way to go around an obstacle on the route	5.19	5.03	4.62	4.16
Finding the location of a chemlight that is marked on the map	5.77	5.60	5.47	4.65
Ease of engaging touch options	6.32	6.06	4.90	5.48
Ease of enlarging map	6.41	6.16	5.16	4.61
Ease of moving map in north, south, east, or west directions	6.41	6.22	5.53	4.90
Ease of zooming in and out	6.35	6.09	5.29	4.67
Planning a route over a kilometer (km) long in flat terrain	5.26	5.29	5.26	4.32
Planning a route less than 100 meters (m) long in flat terrain	5.33	5.45	5.23	4.70
Planning a route over a km long in hilly and mountainous terrain	5.10	4.81	5.00	4.24
Planning a route less than 100m long in hilly and mountainous terrain	5.00	5.05	5.00	4.29

Comments**No. of Responses****2D-NU**

Excellent.	1
Great!	1
Easy to use.	1
By far, my favorite. Simple, organized, and easy to follow. Note: Dropping chem lights was much easier after practice.	1
Easy to navigate using this. You always know where you are and where you are heading.	1
It was extremely easy deciding what direction you are facing. This made it easy to see what direction you needed to go for the next objective.	1
Easy to figure out the buildings based on looking around and comparing to map.	1
A lot easier to orient which direction you are going in.	2
Very easy to use and adjust in the 2D north up view setting.	1
Fixed north orientation made it easier to maintain spatial awareness.	1
I'm becoming better at using the system in general.	1
I like the satellite picture to follow over a non-easy topo paper map. Call for fire would be awesome with terrain location ability of the phone.	1
Very easy to locate points in relation to N and much less of a headache than AR.	1
Compared to the AR, this was a breeze. Felt like I was using a paper map and compass without the hassle of either.	1
Since the compass did not move, it made it simpler and easier to follow.	1
Good for maneuvering, not so good for micro identification.	1
Smart phone was easy to follow and this view it seemed to be easy to drop chem lights when I wanted them.	1
Hard to place chem lights on exact location. If I could use the smart phone to place a point on the terrain in front of me (laser/crosshatch), could it more easily correspond to a digital point on the smart phone display?	1
Dropping chem lights is fairly easy but mistakes can easily be made. Luckily they are easily fixed.	1
Dropping a chem light between buildings can be difficult if the display area is too small for your finger.	1
Difficult to make symbol (chem light) locations in this mode and know if they were placed on the actual target.	1
The only real problem I had was the placement of markers for objects that were not at my present location. If the object was off some distance from my position, I felt uncertain in regard to placement accuracy.	1
Difficult to recognize which building is which in the simulator screen.	1
Difficult to always match up buildings on map to screen.	1
Determining which building I was at was a little difficult because my location was off on the map.	1
Icon and location of the site did not match. It was hard to move around obstacles.	1
The blue chevron on the phone was slightly off which made it slightly difficult for map-to-video correlation.	1

<u>Comments</u>	<u>No. of Responses</u>
Placement of chevron was off on map to relation of character.	1
Map to location chevron and simulator was slightly difficult to coordinate.	1
Estimating distance from current location to target was difficult.	
The GPS was slightly off making some of the directions difficult to follow in areas with smaller avenues of motion. The map showed me walking on top of buildings instead of beside them as I saw on the screen.	1
Does not zoom in/out far enough to my liking.	1
<u>2D-R</u>	
Overall, a great tool.	3
The display overall is great and easy to use.	3
Very useful and much more efficient than standard use of map land navigation.	1
So far it is the easiest way to navigate on the map. Not difficult to find a corner of a building.	1
Easy to orientate self to map and move in directed direction on this map.	1
The rotation of the map was great and touching the screen worked excellent.	1
Easier and faster when finding direction.	2
Size of icons is just right.	1
This map is very effective in keeping your bearings with your surroundings, but causes a little confusion when a specific direction (N S E W) is requested.	1
Trouble maintaining orientation when directions (N S E W) were given. Distances were difficult to gauge without a scale.	1
Choosing to drop an icon on the map is easy; however, placement accuracy is more difficult for individuals with larger fingers.	1
Sometimes found it hard to orient which direction I was going in. Maybe if the compass icon was more detailed it would be easier.	1
At one point getting around an obstacle, I went the wrong direction on the route; had to double back and reorient myself.	1
If the blue chevron could constantly stay centered, that would make the guidance system perfect.	1
It was difficult to determine obstacles until you are on top.	1
It was a bit difficult to determine distance.	1
No way to judge distance when you zoom in/out. Scale for boxes?	1
A bit of clarity would help movement.	1
Could add a button to drop symbols or chem lights on your exact location instead of tapping the map screen and possibly adding the symbol to the map in the wrong location.	1
The dropping of the chem lights is not as precise as it could be.	1
Coordination was a bit difficult due to the lag and moving north. The moving north doesn't seem to be helpful in this particular scenario.	1
When given instructions or descriptions in cardinal directions, it definitely took a little longer to translate that into a place on the map. Unsure of the benefit of the rotation map/N symbol.	1
I didn't like the map rotating as I rotated. It was hard to estimate distance.	1

<u>Comments</u>	<u>No. of Responses</u>
The rotation of the map on the phone makes it difficult to locate yourself at a fast pace.	1
The rotating map was a little difficult. It made it harder to orient which direction to move unless you were constantly monitoring it.	1
Letting objects rotate around me makes pathfinding tougher when referencing the map.	1
Knowing which building is which is confusing when moving and spinning on the fixed axis. Constantly having to track N is mildly touchy but not difficult except when you need to approach from a specific/side.	1
<u>3PP</u>	
Excellent; 3D is very useful.	1
Easiest to use out of all other programs.	1
The map is well down and easy to use.	1
The map was effective for depth perception.	1
Easier to identify and move towards icons on 3D rather than AR.	1
Easy to correct when you got off course since direction and path were highlighted.	1
Labeling where you had been was a great idea. Having the WP with ascending numbers was also a great indicator of direction.	
It seemed that as I tried to move the map north or south, it zoomed in at the same time.	1
Being able to use touch screen worked great, but where I was placing markers and where they showed up were off.	1
Lag time can take a little getting used to.	1
Placement of symbols (i.e., chem lights) can be difficult due to size of fingers causing actual placement to be off.	1
Dropping chem lights in exact location difficult due to large fingers. Have a pen-like selector would allow more accurate location drops.	1
Placing items was very difficult to perform. Objects seldom appeared where I thought I was pressing.	1
Dropping chem lights could be better.	2
Overall, easy to navigate, but at times was difficult to put chem light in exact desired spot on map.	1
Dropping chem lights on target only once was very rare. Had to move and re-drop almost every point.	1
Accurately dropping chem lights was very difficult in this mode. They seemed to fall very far from where I intended them to go.	2
Very difficult to drop a chem light in the correct spot. The map didn't follow me; I had to move the map to keep myself centered in it.	2
Dropping a chem light on a point was difficult the chem light was always shifting.	1
Determining when I was on a waypoint was difficult if I wasn't directly on the path.	
Trying to very precisely drop chem lights can be a little challenging on the touch screen. Perhaps a pen or pin device could be used in order to precisely drop chem lights.	1

<u>Comments</u>	<u>No. of Responses</u>
It's difficult to precisely place chem lights because one has to guess a little lower than one would think. I really did not see a benefit with the 3D perspective.	1
I tried to change the color of a chem light I dropped, but was unable to access the options menu, even with the map fully zoomed in.	1
3D was not very good. I think 2D view was a lot easier and user friendly.	1
This type of map took getting used to. The first four markers needed moving around to get placed right. After getting the hang of it, I found it easy as the other maps.	1
Marker placement on movement route map was difficult due to inaccurate placement. Placement on village map was not an issue. Tracking buildings edges due to shadows in image was difficult. Image shadows were on the south side of the building.	1
It was hard to determine which side of the building I was looking for.	1
Obstacles not on map. Maps would have to be super up-to-date to help navigate around some obstacles.	1
When I tried to zoom in on the map, it would not zoom any more. Would have been nice to zoom slightly further.	1
Hill and mountainous terrain not present in scenario. Obstacles not present on map, unable to judge distances and location of C-wire until moving character on screen and moving to location obstacle.	1
<u>AR</u>	
Once on the path, following it was relatively easy.	1
The touch screen for the map is really good.	1
Finding places described in cardinal directions relative to known points was harder than any other mode.	1
The only trouble I found was finding the building # in the AR mode on its "lollipop" stick. I double checked numerous times different colors that match physical copy of map would help.	1
Building markers did not actually mark buildings.	1
Building names should "float" on left or right side as they pass out of view. Should also be able to select bldg to highlight against background (would create third arrow on mipmap).	1
The reality map was more challenging since on a small screen as opposed to the human eye sight and how much you can see.	1
Once you place certain number of icons on the map, it becomes harder to mark any other targets in that same area.	1
The "N" on the paper map was pointing in a different direction compared to "N" on Smartphone.	1
If you get off the route, I found it hard to navigate back on to.	2
Place route on ground?	1
The route lines blurred often and were difficult, if not impossible, to find once you walked a certain distance.	1
This method was extremely difficult with blind spots and finding targets.	1
It is slightly difficult to drop chem lights at specific locations because you have to be a certain distance away.	2

<u>Comments</u>	<u>No. of Responses</u>
Placement of chem light/markers is difficult. Would rather have a “drop” chem light at my location. Estimate distance to target almost impossible if focused only on eyepiece. Icons are so large that they block the view. Information overload/frustration. Spent most time looking at eyepiece.	1
Difficult to make symbol (i.e., chem lights) locations in this mode and know if they were placed on the actual target.	1
Difficult to accurately drop a chem light at the intersection of the object and ground.	1
The chem lights and markers were very difficult to see around/through.	2
Marker size was very disorienting.	1
The chem light markers fill the screen when they are approached, making it impossible to see other things. So some level of transparency would make it easier to navigate, while still demonstrating the nearness of the item (chem light, waypoint, etc.).	1
Map icons get in the way of AR map display you do not adjust in size.	1
The location markers were a bit too large.	1
Had to back track in order to place chem lights.	1
Too many symbols on the screen. Hard to differentiate between chem lights and markers. Difficult to place chem lights where they belong on the screen.	1
It would be great if we could use the crosshairs to look at (aim at) the location to more accurately place markers.	1
Need indicator in corner that always points toward route and another that points to waypoint.	1
This would be better if the user had control with the markers sizes and opaque (see through) values. I think it would be helpful if the chem light markers would lay down on the ground until the user stops walking or something to that nature.	1
When chem lights are dropped, I keep overshooting the targets. Use of a stylus could be helpful.	1
In the small display in the bottom corner it would have made it easier to orient locations and checkpoints had it displayed features and points on it.	1
Much more complicated and somewhat confusing.	1

2. Using the scale below, please evaluate the following features of this interface.

1 2 3 4 5 6 7
Extremely bad Very bad Bad Neutral Good Very good Extremely good

FEATURES	MEAN			
	2D-NU	2D-R	3PP	AR
Size of symbols (e.g., chemlight)	5.91	5.84	5.48	3.53
Size of symbols as you zoom in and out of map	5.88	5.87	5.45	3.95
Size of text	6.00	5.87	5.29	4.29
Size of grid lines	6.03	5.93	5.61	4.75
Size of the overall map	6.28	6.16	5.68	4.83
Map colors	6.44	6.42	6.26	5.84
Placement of text	5.97	5.77	5.48	4.47

Comments

No. of Responses

2N

Excellent.	1
Easiest to use for this specific simulation.	1
Very useful and easy to use.	1
Great graphics, easy to find an object. No problems marking an object.	1
The text, colors, zoom in/out work perfect on this map and make navigating very easy.	1
All sizes were good.	2
No issues with map or symbols with this map.	1
Did not obstruct map, unlike AR.	1
Great job on the interface. I had no trouble understanding what I was looking at.	1
Easy to follow and discern information provided, configuration of chevron to map offset.	2
More realistic due to the fact that when you are navigating outside, you are not rotating map as you were in other map configurations that were tested.	1
Speed wise, Smartphone was able to keep up with actual speed of moving.	1
Was able to focus much more on the actual screen and not the phone.	1
Less strain on eyes and simpler to orient oneself.	1
The size of the chem symbols on the map is hard to land just right with big fingers. You could only zoom in so close to be accurate. Would be nice to zoom in a little closer to better drop chem lights.	1
I should have zoomed in closer to see a more accurate depiction of where I was in relation to WPs.	1
Zoom intervals too large.	1
Problems seeing text on top of buildings without zooming in quite a bit. Problems with placement of text on buildings.	1
I would prefer that symbols (chem lights, etc.) were a little smaller.	1
The route lines could be a little smaller so you could still see them on the map but it wouldn't cover more terrain image than necessary.	1

<u>Comments</u>	<u>No. of Responses</u>
<u>2R</u>	
Excellent.	1
I like the system and the application.	1
The interface is easy to use and well done.	2
All are good.	1
So far, easiest to use.	2
Could really make a life saving application for soldiers on the battlefield and make maneuvering a lot more efficient.	1
Practical.	1
The placement and allowing the map to move is great.	1
It was easy to see beyond the symbols to see what was actually on the map.	1
Easy to follow.	1
Easy to read.	1
Maps were really good and clear.	1
Map is easy to read because it is like the GPS systems of our Smart phones.	1
Text is very easy to read on the screen.	1
Anyone who has used a cell phone, GPS or a regular one could do it with no problem. It is actually easier to use.	1
Much better than 3D.	1
Easy to discern amongst targets and locations.	1
Size of some symbols can be reduced.	1
For me this rotation is more difficult to orient to without testing longer and learning.	1
I would not get rid of this option because it is useful to other people.	
Sometimes you need to stand by and wait until Smartphone map location will keep up with your actual location.	1
Only complaint is that the chevron goes off the map when you're moving.	1
Not always easy to verify where chevron was on map in relation to screen.	1
Placement of text to ID buildings is difficult to use when reorienting to move to a specific side of the building. The ID factor for the building is the orientation of the characters so when they move constantly, I feel like south is moving unless I check where north is in the corner.	1
Building markers were difficult to identify on map.	1
<u>3D</u>	
Excellent.	1
The maps are really easy to follow.	1
The colors and text of map are great.	1
Map on phone easy to read, clear lines, not cluttered.	1
Works well with the 3D view to help see the distance of objects marked.	1
The interface is well done and easy to use. After little practice it is almost natural.	1
Easier to navigate through city and finding building numbers.	1
Given it's a Smartphone, I'm not sure how much bigger the map can be; but it did feel small at times.	1
Maps do not account for obstacles and the best way to maneuver around them.	1

<u>Comments</u>	<u>No. of Responses</u>
This sky view takes getting used to. It was not as accurate to me as the straight overhead view.	1
Symbols made the screen cluttered at times.	1
Size of casualty and friendly forces need to be smaller; they are oversized and overwhelm the visual.	1
Placement and size of text in the city to identify buildings was difficult. Darkened shadows obscure the text.	1
Difficult to see the building identifiers when I was in the village. They blended in with the buildings.	1
The waypoint labels should be a higher contrast color so that they stand out more. Black labels were difficult to see on the darker map.	1
Angle view distorts and overlaps text.	1
<u>AR</u>	
The text was great!	1
I like the size of the symbols and of the grid lines, but sometimes they can block out your vision entirely.	1
The symbols on the map all clustered together.	2
Symbols too large.	1
Symbol size was too big. You could barely see the text on the actual map. It was hard to understand the distance between placed icons on the screen. Hard to determine which building is which.	1
Symbols are too big. The writing on the ground is hard to read unless you are right on top of the writing.	1
The size of the symbols were very large and obscuring other targets and visuals.	2
Symbols should be transparent so that you could see through them. They are also slightly too large.	1
The symbols on the map were extremely large to start and were unable to tell when one was passed. Once size was reduced, the size was much easier to see and follow.	1
I used the printout map to navigate more than the phone.	1
Buildings should have labels float on them. Should be in high contrast color – not black. Need to be able to set “groups” of chems and minimize unnecessary groups. Should be able to shrink icon size or placement.	1
Building numbers/labels were not on buildings.	2
Difficult to tell what waypoint I was at. I did not realize the number was written on the ground and even then it was difficult to read.	1
Difficult to read the text on symbols. Some symbols (casualty, friendly) were missing.	1
Text hard to read when parallel with ground (black WP hard to see at distance). Difficult to identify bldg #s when close or around multiple bldgs, in that mode only.	1
The interface is crowded. It also is a bit challenging to stay on the proper path if you deviate at all.	1
When in the actual urban environment, buildings were very difficult to identify.	1

<u>Comments</u>	<u>No. of Responses</u>
With a higher number of chem lights in the area, it becomes very difficult to navigate at all due to the markers blocking view.	1
Hard to place chem lights where I wanted.	1
Need to have the chem light option menu first as opposed to scrolling down to add new system.	1
I was so distracted by the map that I had a terrible time following or finding the actual target. As it is, I would not want this in real world application. If the user could adjust setting to personality, I think this would be a great product.	1
Only trouble I found was when a target (i.e., wounded soldier) was hidden behind medic-cross symbol.	1

3. Overall comments on this map interface:

<u>Comments</u>	<u>No. of Responses</u>
<u>2D-NU</u>	
Excellent, north being fixed is great.	1
Best map I used today.	
Very good.	1
This program is awesome overall.	1
Overall, user friendly.	3
Overall easy to use and navigate.	2
Overall successful.	1
Much easier to use than the AR method.	1
Practical.	1
Very neatly laid out display that makes it easier to stay oriented.	1
It would be easy to use this system to move from one grid location to another or to follow a preset route.	1
Very simple interface; makes it easy to shoot azimuths and find a general direction. The steady N also helps to keep our bearings.	1
I preferred the fixed north orientation to the rotating map. It made it much easier to maintain spatial awareness.	1
Locating a specific side of a building (i.e., west, east, etc.) was easier in this map than in the 2D-R map.	1
It was easy to use and correct when mistakes were made.	1
This interface is easier to navigate through urban terrain, but easily lost on track with no path.	1
Everything about this interface was intuitive and simple. The only problem was marker placement, and that was not very significant if I was attempting to place a marker at my location.	1
Estimating distance to WPCs in relation to WP lines was frustrating. Distance to enemy hostiles is difficult to mark on the map.	1
Distance judging is hard but that may stem from the simulation more so than the interface.	1

<u>Comments</u>	<u>No. of Responses</u>
More difficult to follow the route and move to waypoints and other objectives in this map than in the 2D-R map. In other words, 2D-R was easier.	1
Difficult to estimate distances and difficult to place chem lights exactly.	1
I think that multiple options should be kept for style and use of every personality. I personally like the overview 2D-NU where other people will like the rotation. Keep all of it.	1
The chevron being slightly off made moving around the MOUT site difficult.	1
Location of chevron and orientation not completely in sync.	1
Only issue was with location of chevron on map.	1
N up map can be a little confusing when making multiple turns; compared to the rotating map.	1
There was some small lag in time which almost made me cross over my paths before I was ordered to.	1
Some difficulty with the lag between the screen and the map caused me to overrun the waypoints in some cases.	1
Icons did not correspond with the actual locations and it was somewhat hard to gauge the distance throughout the course.	1
Had a little trouble at some points with the map orientation when navigating around buildings.	1
Building identification was hard due to text/bldg resolution. Map locations with multiple items become muddled.	1
<u>2D-R</u>	
Awesome map interface.	3
The map interface was the easiest to determine orientation and to navigate through the urban environment.	1
Great.	1
Easy to use.	6
Intuitive.	1
Easy to follow lines.	1
Chem lights are easy to place and track.	1
Very easy to follow the routes and place things on the touch screen.	1
Easy to navigate and maneuver.	2
Easy to read.	1
Easy to follow.	1
So long as you are always aware that your map orients around you, this was by far the most enjoyable method of navigation.	1
The rotation compass actually makes it easier to find sides of buildings (for me, anyway).	1
Very easy to follow paths and locate items, but when trying to envision the relative placement of objects in N E W S directions, a moment of mental readjustment is required.	1
If the blue chevron could stay centered, that would be ideal.	1
The distance is hard to judge.	2
Map is not good for navigating around obstacle.	1

<u>Comments</u>	<u>No. of Responses</u>
Effective for all facets except for specific direction requests.	1
Easy to drop items.	1
I noticed it took a little more mental thought locating sides of buildings when the N arrow was not fixed.	1
Text on buildings, adding compass reference rather than fixed north. Arrow tells you which direction you are headed not where north is for making longer distances.	1
Keeping yourself oriented was a little difficult on the rotating map.	2
The changing orientation of north made it difficult to maintain spatial awareness.	1
The green return box is helpful when I traveled off the map.	
One problem with this orientation is that one can confuse which direction to go on the route. In other words, they can be turned around. However, this may seem more problematic in a virtual environment and it may be a no issue in the real world.	1
The zoom in and out function is a little difficult to use and I didn't like that I had to re-center the map on the chevron as I was moving.	1
Placing chem lights in an accurate location is a little difficult with large fingers.	1
As the map changes, you must mentally redraw your position relative to the route.	1
A fixed perspective allows you to pathfind to and from your point of departure without known waypoints changing position.	
<u>3D</u>	
Overall, an excellent tool. Very impressed.	2
Good overall.	1
Easy to use and well done.	3
Overall, much easier to navigate throughout simulation.	1
Easy to locate and mark targets.	1
Fixing mistakes is easy and best of all the map and interface make sense.	1
Easy to pick up after only a few minutes once lag is decreased. This could definitely make land navigation a breeze. May cause a little confusion with map always adjusting around soldier's location. It's nice to be certain that the top of the map is always north.	1
3D map is really good for estimating distance.	1
Extremely easy for direction (N,E,S,W), distance and location of buildings that had coordinates/labels attached to them.	1
This view is easier to follow on a route than the AR view; but judging distance (while marking things from afar) is difficult.	1
In general I had no issues navigating on the map, except for finding a particular corner of a building.	1
The map mode was good for obtaining an overall picture of the area, but I found it harder to follow than some of the other map types.	1
Easier to visualize the town in 3D, but more difficult to follow the path. There was significant lag that made it hard to stop on waypoints and get back on the path.	1
It is very applicable but I still prefer the 2D map with north up.	1

<u>Comments</u>	<u>No. of Responses</u>
Didn't see a way to go around obstacles on map (this question appeared in the previous questions), and the lag updating points as you changed direction could be slightly improved.	1
This map interface was more difficult in general.	2
Had a hard time dropping chem lights and other items in the specific location.	1
The navigation wasn't as much of a problem as the placement of chem lights.	1
Placement felt inaccurate and took multiple attempts to get in correct location.	
Had trouble placing chem lights exactly where I want them. Much harder to do in 3D mode.	1
Once a chem light was dropped, it was difficult to select and move that chem light.	1
It seemed the blue arrow that was my symbol was too close to the bottom of the screen a lot of the time. That made it difficult to drop chem lights at my location because I would have to watch where I wanted.	1
The placement of the map is difficult to get oriented to by following route from map on phone.	1
It was easy to forget to watch the monitor and focus only on the phone.	1
I think it would be easier to not use this method.	1
Not sure the 3D map really gives an advantage over the 2D map, and may have several disadvantages (higher hardware requirements for computing, less accurate chem light drops, etc.).	1
Could use the ability to zoom in more for accurate placement of symbols (i.e., chem lights) on the map.	1
The 3D view is harder to use as far as zoom and trying to see where you are on the map.	1
Zooming issues even at max zoom unless you move the map so that the chevron is directly in the bottom center, the map looks smaller. Perspective distance at the viewing angle.	1
Must be more aware to your surroundings.	1
Harder to find markers due to the angle.	1
Colors for some labels could be made brighter.	1
<u>AR</u>	
Great graphics overall.	1
Was fun.	1
Good for distance and up close.	1
Easy to maneuver in the area.	1
I like the idea and think it will be very useful.	1
Makes land nav less stressful knowing you have this technology (i.e., finding direction very quickly).	1
Like the route lines and WP to find objective.	1
It's ok, but it will take some time to get used to.	1
Simply, the objects need to be a bit smaller to make it worth using; otherwise it worked great.	1
The interface was too crowded, but it is easy to use overall.	1
I believe with some practice it would be easy to use.	1

<u>Comments</u>	<u>No. of Responses</u>
Can be an effective tool to see where things were on a given point, but it is difficult to manage while navigating. This method should not replace general foreknowledge of the AO, better as a supplement.	1
Works really well for following a pre-arranged route, but trying to look at surroundings becomes difficult with all the labels and lines.	1
Seems to have been some sort of malfunction and it made the map almost useless. I can see the advantages of the system, but I was frustrated with my experience.	1
I would suggest making the markers or symbols on the map transparent in order that you could see through them if you were too close. This would still allow them to be visible from a distance and up close without blocking your vision.	2
It was much harder to orient oneself in the urban environment. Buildings were difficult to identify, and I was nearly totally blinded by markers in the augmented reality view.	1
Building numbers should be marked more clearly.	1
Orientation as a whole is difficult to follow and relate to mission as a whole.	1
The lag was significant, making it difficult to orient yourself.	2
Icons need to be translucent.	1
AR mode needs a two finger mode to set location/height. This would prevent “higher” presses registering as “distant” presses. Pinch to move selector point closer – spread to increase distance. Overall, AR becomes cluttered and confusing in tow, and easily lost in field.	1
Make symbols user friendly with setting changes.	1
Make symbols lay down until the user requests them to pop up.	1
Make symbols smaller and position symbols closer to targets.	1
I prefer the 2D views for navigating. The number of symbols on the screen is distracting. It was difficult to know when I reached a waypoint or the release point.	1
Markers on the map grew larger as you approached, obstructing your vision of waypoints, med points, etc.	1
Make it so a person can point to the middle of the screen at the location of the target point. If I want to pick the point I’m standing, point phone at my feet then select the marker. I would like a crosshair and laser dot on the screen to point and a button to click that would place the target point. Like a camera picture merged with a crosshair of a gun and shoot their feet.	1
Takes a while to get used to view angle and placing accurate chem lights and standing on specific point.	1
Very hard to place chem lights on targets at 0°.	1
The chem light placement was frustrating, as was the size of the symbol on the screen.	1
It’s difficult to determine your spatial understanding (distance from one point to another).	1
I ended up focusing more on the map, which was woefully inadequate in orienting my location and showing the routes. The chem light placement was also extremely difficult.	1

<u>Comments</u>	<u>No. of Responses</u>
A little bit difficult at times on a Smart phone; would be great as an eyepiece “heads-up display” as noted at the beginning.	1
More confusing and not as user friendly as the other systems; would confuse many soldiers I fear.	1
More complex and feature full than necessary at the AR level. Floating directional arrow with distance to point counter would allow for better navigation.	1
Hard to navigate left/right while moving.	1
Can’t distinguish where items are.	1
Would like to drag-n-drop icons; icons too large; become visual obstacles.	1

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Appendix C. End of Experiment Questionnaire Results

END OF EXPERIMENT

SAMPLE SIZE (N) = 32

Map Type
2D North up map (2D-NU)
2D Rotating map (2D-R)
3 rd Person perspective map (3PP)
Augmented reality map (AR)

1. Which map type would be best for the following tasks?

Tasks	Number of Responses*			
	2D-NU	2D-R	3PP	AR
Dropping a chemlight on a given grid coordinate	19	11	1	2
Dropping a chemlight on the map to show the location of an object off your path	14	13	2	3
Estimating distance	15	10	6	2
Following a pre-drawn route	17	12	2	3
Keeping track of your orientation	24	6	2	1
Determining which building you are facing	17	8	5	2
Determining the best way to go around an obstacle on the route	20	7	0	2
Finding the location of a chemlight that is marked on the map	14	13	3	6
Which map is most intuitive (i.e., easy to use/understand without much training)?	22	10	1	0
Ease of engaging touch options	22	11	2	1
Ease of enlarging map	19	14	3	7
Ease of moving map in north, south, east, or west directions	19	13	2	1
Ease of zooming in and out	21	14	0	0

**total number of responses may exceed N as some participants chose more than one map*

Comments

No. of Responses

Any would work about the same in my opinion.	1
A mixture of modes would work best. Different modes make sense at different times and situations.	1
2D-NU	
2D-NU was the easiest to use, and fastest interface.	8
2D-NU made me feel confident in controlling what I was doing and was simple to figure out.	1

<u>Comments</u>	<u>No. of Responses</u>
Simplicity of 2D-NU really worked well.	1
Easiest to orient my direction when north stayed up as in 2D-NU mode.	1
I was able to maintain my spatial awareness and navigate in the town with 2D-NU.	1
2D-NU would be my choice.	1
2D-NU best simulates an actual map.	1
2D-NU map never rotated which let your mind be at ease while moving and receiving orders.	1
Although other map types would be helpful, in this particular scenario, 2D-NU seemed to be the most helpful.	1
2D-NU <u>and</u> 2D-R are the same and work wonders.	1
2D-NU <u>and</u> 2D-R were very similar in navigation. Although set N” made it easy to find any required object.	1
Most of these basic tasks would be easiest in either the 2D-NU <u>or</u> 2D-R modes.	1
2D-NU <u>and</u> 2D-R are already being used in Smartphone’s for maps and directions. It would be easiest for modern soldiers to adapt to and use efficiently in the field.	1
<u>2D-R</u>	
2D-R offers one of the best interface features and easiest to use.	3
I might get used to the 2D-R if I had more practice.	1
2D-R was the map that took the shortest amount of time to understand.	1
2D-R was the most intuitive for me.	1
2D-R needs to be able to quickly and easily identify the N S E W side of a building.	1
2D-R is fine, but for me I can lose my sense of orientation if I am always “moving up” a screen.	1
<u>3PP</u>	
With 3PP and AR I felt that I could not accurately mark targets.	1
3PP made it easier to estimate distance and find existing chemlights on the screen.	1
3PP was pretty useless.	1
<u>AR</u>	
Some benefits to marker placement accuracy with the AR.	1
With more training, the AR could be more helpful.	1
AR is a great idea, but there should be a better way to plot information like a separate small screen that is in 2D and maybe handheld; also with a stylus or something.	1
I like the potential of AR. Needs to have adjustment ability given to the user as stated in my (AR) evaluation.	1
Maps are easy to use and follow. Routes on AR map are more difficult to follow; routes would be easier to follow if on the ground.	2
AR map type was difficult to determine whether an icon is behind or in front of the building.	1
The AR option is too cluttered right now. It makes it challenging.	1
The AR was the most cumbersome and straining!	1
The AR had too much going on and could be overwhelming.	1
Downside of AR was large symbols and poor overlay of the planned route to follow; also dropping symbols on a certain grid.	1

2. Which map type was best for the following features?

Features	Number of Responses				
	2D-NU	2D-R	3PP	AR	NR
Size of symbols (e.g., chemlight)	18	12	1	0	1
Size of symbols as you zoom in/out of map	21	10	0	0	1
Size of text	17	12	1	0	2
Size of grid lines	16	9	4	1	2
Size of the overall map	16	11	1	1	3
Map colors	19	8	2	1	2
Placement of text	17	12	1	1	1
Best overall map	20	9	1	1	1

Comments

No. of Responses

Map colors were excellent on pretty much every map type.	1
2D-NU and 2D-R maps are both excellent.	2
I love the ease of the 2D-NU; user friendly.	3
2D-NU was a lot less confusing looking directly down at targets and symbols/text was not obstructing any view.	1
2D-NU is a close second, but for the first time around I thought the 2D-R was much easier to use. However, I'm sure with time that 3PP and AR would become easier to use.	1
2D-NU was by far the best in terms of design and functionality. It is easier to tell a change of direction by looking at the chevron than the compass arrow.	1
I think the optimum system would be a combination of the 2D-NU and the AR. The AR would be the mode you are in most frequently but the 2D-NU would exist to give you a birds eye perspective and more of an overall picture of the area you're working in.	1
I don't see any benefit or difference in 2D-NU and 2D-R; it would come down to personal opinion.	1
I did not notice much of a difference in size and color for 2D-NU, 2D-R, or 3PP.	1
2D-R map took a little getting used to, but once accustomed, it was by far the best map with the 2D-NU a close second.	1
Response time of rotating map (2D-R) might be too slow to be useful; most soldiers probably already well versed in N-oriented maps.	1
I like the potential of AR. Needs to have adjustment ability given to the user as stated in my (AR) evaluation.	1
AR had symbols that were distracting and made it difficult to navigate.	1
Symbols were quite oversized on AR. For that reason it was hard to mark an object with chemlight.	1
AR map was the most difficult to use and follow routes and identify buildings when close.	1
I don't like it when the (2D-R) map rotates; I lose sense of direction.	1

Comments**No. of Responses**

Would love to have used 3PP map on mountainous terrain.

2

I would prefer symbols to be a bit smaller.

1

3. If you could only choose one type of map, which one would you choose?

Map Type	Rank
2D North up map (2D-NU)	20
2D Rotating map (2D-R)	10
3 rd Person perspective map (3PP)	1
Augmented reality map (AR)	1

Comments**No. of Responses**

The simpler maps seemed more practical for tactical uses.

1

I love the ease of the 2D-NU .

1

2D-NU is easier to view map in its whole.

1

2D-NU is the most versatile for completing different tasks.

1

2D-NU – command view; 2D-R – PL view; 3PP – PSG view; and AR – individual/
simple movement view.

1

Judging distance was the easiest on 2D-NU and 2D-R.

1

2D-NU and 2D-R were very easy and understandable for use.

1

2D-R was the easiest to use and navigate.

1

Using rotating (2D-R), I'd rather it tell me which direction I'm going.

1

2D-R seemed un-useful, rather than helpful, in my opinion.

1

I think if you could have two of the maps, 2D-NU and AR would be the best option.

1

AR has a lot of potential, but in these instances it wasn't the most intuitive.

1

AR would be more helpful (if adjusted to eyewear) in a dangerous urban
environment.

1

I like the potential of AR. Needs to have adjustment ability given to the user as
stated in my (AR) evaluation.

1

AR is annoying because of the icons. If they were transparent or smaller, it would
be number 1.

1

With AR the symbols filling the screen, when you get close to them, obstructs your
view of everything else, including the other symbols. They need to have some sort
of transparency or stacking function that lets you see what's behind the closes one.

1

AR would be detrimental to me if I was trying to navigate.

2

AR needs to improve lag time, which I know is not the software but the hardware.

1

3PP is more productive when plotting.

1

3PP would be helpful with missions on hills, mountains, etc.

3

3PP would probably be better for more diverse terrain.

1

I found little benefit with the 3PP view.

1

3PP is overkill. With the other options we have, 3PP is not an advantage (in my
opinion).

1

Comments**No. of Responses**

One downside of all 4 map types is that you have to stand by and wait until chevron catches up with you. 1

4. What is best way to move your cursor to a specific grid location?

	Number of Responses
Manually type in the 10-digit coordinate	8
Use a “go to” dialog box to choose from a list of plotted entities (e.g., PL symbol) to move to their grid coordinate on the map	2
Touch a location on the screen	17
Other (specify below)	2
NR	3

Comments**No. of Responses**

For a specific grid, it will be better to type it in manually for accuracy. 2

Manually would take more time, but if accuracy is the key, then that is the best way.

A “go to” dialog might quickly become overwhelmed. Imagine scrolling through a list 3 miles long because of all of the points that had been added. 1

“Go to” if, however, there are a lot of points (6+), it would be cumbersome. 1

Input data for “where to go.” 1

Check grid location by tapping. 1

Best way is to place finger on grid to point it out. 1

Easier to use touch screen to get an approximate location of an object. 1

Touch is the fastest and easiest way, although it may not be accurate. 2

Touch, but then I have to drag it to the more exact location. Chemlights do not fall where I think I’m touching the screen. Not very easy to move/edit chemlights. 1

Would prefer to drag-n-drop an icon with a crosshair to show where it will be placed.

If grid plots are available on touch screen, this would likely be the best option. 1

Love the google earth ability. It is important to still have grid coord input method to find a specific target given from someone else. Scrolling would not be time efficient. 1

Other: a stylus, pin, cursor, or mouse. 1

5. If time and money were no issue, what additional features would you like this technology to provide? (For example, are there any features that you’ve seen in games or movies that you would like to have?)

Comments**No. of Responses**

Simple is sometimes more effective and efficient. Too many extras slow down system and clutter screen. 1

<u>Comments</u>	<u>No. of Responses</u>
Highlight objects on screen and know my distance from the point.	1
For marked buildings, labeling each side with a small N S E W or even putting a N-up symbol on top of the building would make it a lot easier; though the trade-off would be a busier map (more symbols, etc.). Also I think the ability to zoom in more closely can add accuracy and clarity for the symbols.	1
Be able to see building numbers even if another building is in the way.	1
Features like seeing through building and see people from far away.	1
I was able to play with an eyepiece monitor/camera at a soldier expo. If this system were integrated into that system it would be great, along with a secondary input device.	1
More real time information displayed in the HUD.	1
A real time IR view to notice potential threats.	1
Infrared.	1
Maybe someday they would be able to provide live time maps via drone planes with cameras in order to give the most current high resolution over head image. This could help with things like barriers that you might not see on a map if the map photo was taken before the barrier was built. Maybe spy planes would be able to link up directly with the mapping device.	1
Maybe higher resolution on the maps.	1
Add a feature on the iphone that places a point on the terrain in viewing in AR that will identify with a point on the actual map display.	1
It would be good if you could touch something in AR mode and get its distance from you.	1
Spatial two finger control for AR (as seen in all space games) nav and target arrows (most air/space fighter games).	1
Distance markers to points, the distance to the point ahead of you are two major terrain features.	1
Instead of just dropping one chemlight to mark the wire, be able to mark the whole wire so soldiers know where the openings in the wire are located.	1
Zoom features on the AR. The targeting of the hostiles could have been the most accurate in the AR mode if you could just zoom in enough to clearly see where they stood.	1
Change icon size on AR map types and have them indicate the exact location of nonmoving objects from any point of view.	1
In the AR, keep the orientation of the radar fixed up with a rotating compass on the outer ring and points inside adjusting as the person turns.	1
In the AR, if the orientation in the bottom corner had details and features on it; it would be easier to use and locate yourself on the map in relation to what you're around.	1
In AR, the map on the bottom left should have the route on it clearly or as an option.	1
The lag confuses my location.	
Use more pixels on the map.	1
A little bit bigger screens.	1
Speed it up.	1

Comments**No. of Responses**

Crosshair and camera click targeting. Everyone on this system would have a nav point over them like Halo. The phone could display orders in a corner or overlay then fade back to the map, and fade back last orders when needed.	1
Communication technology between team members; voice controls.	1
A way to see enemy would help if possible.	1
Enemy locations installed onto ballistic eyewear so no separate device is required.	1
Location of shots fired or enemy movement.	1
Something that could detect thermal readings and/or IED signs would be incredible.	1
I would decrease the lag time and also get better satellite/topographic images stored on the phone.	1
Perhaps use a small pen in order to more precisely place drop points. Additionally, once a waypoint is reached, it would fade away or change color in order to remind you that you have already reached that waypoint.	1
A small pen of stick (possibly attached to glove or wrist) to help pinpoint drop points on little Smartphone screen. I have fat fingers so my chemlights were a little off.	1
Drop symbol at current location button.	1

6. At what echelon should this technology be used? Check all that apply.

	Number of Responses
Individual Soldier	16
Fire team	27
Squad	30
Platoon	27
Company	21
Above company level	10

Comments**No. of Responses**

This technology, if advanced adequately, should be used by every soldier who goes outside the wire.	1
I think if you're going to have a system like this, everyone on the ground should have their own system that links up with their squad/platoon/ company, etc. Everyone could be able to input things in the system but maybe you could turn on layers in order to only see certain people and what they have marked on the map. For example, if you are back at headquarters and you only want to see one individual squad's movement, you could turn all the other squads off. Leaders at the company level could track everyone's progress and continue to issue specific tasks to different platoons/squads/fire teams.	1
Would give great situational awareness to everyone in a company.	1

<u>Comments</u>	<u>No. of Responses</u>
Platoon/squad/fire team leaders because they are the most involved with mission planning/implementation; and are the ones directing where their soldiers are going.	1
Above company can oversee; it would be the most beneficial at the squad/ platoon level. Easier to keep organized.	1
Would be most effective for smaller teams and squads, but I could see it becoming linked together for the higher echelons.	1
Everyone would know where everyone is. It would be easier to coordinate attacks, extractions; everything really.	1
If money is not an issue, then every soldier should be able to use this technology. Otherwise, at least every team leader should have it.	1
Information sharing, call for fire and Medevac applications for this will be useful, so at all levels ideally this would be central to sharing info and every soldier is a sensor.	1
Every soldier would benefit from this technology; however too much input can clutter screen and inhibit effectiveness.	1
With the networking between different devices, the inclusion of symbols from higher echelons might crowd the screen with icons.	1
Individual soldier – movement to points; fire team – team member tracking; squad and platoon – timing/movement/tracking; company – tracking; and above company level – tracking.	1
I think if every soldier had this screen, it would make it difficult to move together. There would be too many distractions.	1
Soldiers in the field would benefit the most from the use of this technology.	1
Not every individual needs this. One leader should navigate the squad.	1
Everyone in leadership needs to know what is going on. But the higher ups can get a brief after missions.	1
It would be good for squad leaders and above to have to help organize, the individual soldiers should be paying attention to what's around them not where they are; that is the leader's job.	1
Should go to the squad leader. Having soldiers and FT all with this technology can break command and control; it would produce confusion. A squad leader can adequately gain information and disperse it as necessary.	1
Leaders should be given the equipment; not cost effective for everyone and could lead to arguments on missions.	1

7. Would you use this technology in combat?

	Number of Responses
No	3
Yes	29

<u>Comments</u>	<u>No. of Responses</u>
It could and would save lives.	2

<u>Comments</u>	<u>No. of Responses</u>
The technology seems to have great potential.	2
If safe from hackers, this technology would be amazing at all levels of operation.	1
If it can adequately mark IEDs, caches, HVTs, etc., then I would absolutely use it in combat.	1
If the platoon leaders transmitted what they had done to squad leaders and they know where everyone's position is then that makes fire team leader like a surgeon when completing mission.	1
As a UAV operator, this would help us know exactly where our friendly units are and where they are planning to go.	1
Definitely would save some time land navigating. Being able to see where your soldiers are at. Speed up the process of Medevac and Hazmat.	1
This program allows the ability to see and plan waypoints ahead of current location, integrating a real view and map/topo into one view as if on the ground.	1
Yes, for planning and at the team/squad/PL level for movement/tracking; PL/company level for tracking; group/formation movement, tracking and planning.	1
This would be a lot better than guessing where a person is on a map. This gives real time location at all times. This rocks until the battery fails.	1
If my options are this or a regular map, I'll easily choose this technology. Only a fool (no offense) would take the paper map.	1
Yes, would make routes easier to follow and save time during movement.	1
Would be useful for finding the objective.	1
I would feel comfortable using 2D-NU to navigate.	1
Would be useful for squad waypoints to rally or flank.	1
Although the AR is in general less practical than the other views, it would be useful if you could toggle it for reasons such as marker placement or route identification.	1
AR would make me nervous if I had to use it in combat.	1
The AR would be 100% better if you had a map reference as to your current location and surroundings.	1
I would find it difficult with adrenaline pumping or explosions going off to carefully place my fat, shaking finger perfectly on target location. I feel a little stick might help this problem.	1
Special training for situational awareness would need to occur for soldiers to effectively use this in combat.	2
If there are route lines, soldiers will only pay attention to that. This means they are vulnerable for different attacks.	1
No confusion of path, what is going to be encountered (in terms of terrain and environment) and share vital info at a moment's notice.	1
Focus on digital lines and emblems would distract from concentration.	1
Not yet. Makes orienting a bit easier, but not at all essential. Simple GPS display is all I would use.	1
It would help in getting from one location to another very quickly, but it could be a problem if soldiers become too reliant on the system and not what is happening around them.	1

<u>Comments</u>	<u>No. of Responses</u>
Yes, but for short periods of time. It's too slow and doesn't mark targets specifically unless you spend a lot of time to accurately plot it.	1
Yes, but only slightly. It takes too much attention away from immediate surroundings.	1
If it worked great.	1
Needs to be more refined.	1
Depends on the level, scope, and intensity. In a firefight, I would not be pulling it out constantly. But to mark a pickup site or a call for fire, it can be helpful if it can be used in a short time.	1
Lag time would need to disappear and the chevron's position on the map would need to more accurately reflect its location. For example, there were several instances where my chevron was located inside a building, when I was most certainly not. Made moving down various alleyways a little confusing, especially in 2D modes.	1

8. Which way would you like to see entities rendered?

	<u>Number of Responses</u>
Floating	6
Laying on the ground	8
Lollipop style	15
Other (specify below)	1
NR	2

<u>Comments</u>	<u>No. of Responses</u>
<u>Floating</u>	
Would be easiest, I believe.	1
Floating blocks out a fair amount of the screen when you get close.	1
You can see them from farther away and more clearly than if they are lying on the ground.	1
Floating but with user changeability of size, shape, style.	1
<u>Ground</u>	
Unreadable.	1
If 2D-NU and 2D-R, then lying on the ground will be convenient enough.	1
<u>Lollipop</u>	
Works great and you can see and make pop-up targets.	1
The lollipop allowed me to see the point or building along with the identifiers.	1
Makes it very clear which point it's referring to. If there are two thick points together, it can be hard to distinguish which is which.	1
The lollipop style lets you know exactly where the target is, so no guessing is required.	1

<u>Comments</u>	<u>No. of Responses</u>
Easier to match with buildings and items.	1
Lying on the ground worked best in 2D-R and 2D-NU scenarios.	1
Best in AR style.	3
It would be better for AR mode. There is little reason to change entity rendering for the other maps.	1
AR or 3PP, which will allow you to see the exact location of the object.	1
For the 2D maps, this doesn't make sense (and since I preferred the 2D maps, lying on the ground is best).	1
As long as "stick" shows exactly what is being labeled so it is easy to understand which object is being marked.	1
Lollipop/floating might work for symbols/targets located much farther away from present location.	1
<u>General comments</u>	
Not important; any would work.	1
The 3PP needs to be improved. It reminds me of Nintendo graphics where at times you can't see a point due to lagging until it is too late.	1
The 2D-R seems to be the most proactive feature at this time.	1
The pie map needs to have the option of N stationary and rotating. I would also like the pie to have the ability to zoom in or out depending on needs of terrain and urban style.	1
Whatever method is chosen, entities should be dramatically reduced in size as the person navigating approaches them.	1

List of Symbols, Abbreviations, and Acronyms

2-D	two-dimensional
2D-NU	2D north up
2D-R	2D rotating
3-D	three-dimensional
3PP	third-person perspective
ANOVA	analysis of variance
AR	augmented reality
CCP	casualty collection point
CFF	call for fire
EUD	end user device
GPS	global positioning system
IED	improvised explosive device
NASA	National Aeronautics and Space Administration
NIE	Network Integration Evaluation
NSRDEC	Natick Soldier Research, Development and Engineering Center
OC	observer controller
OCS	Officer Candidate School
RT	response time
TLX	Task Load Index

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